What's New at DØ

URA Visiting Committee, March 2004

John Womersley – Fermilab

DØ

- DØ is an international collaboration of ~ 650 physicists from 19 nations who have designed, built and operate a collider detector at the Tevatron

Institutions: 36 US*, 41 non-US

Collaborators:

- ~ 50% from non-US institutions (note strong European involvement)
- ~ 100 postdocs, 140 graduate students

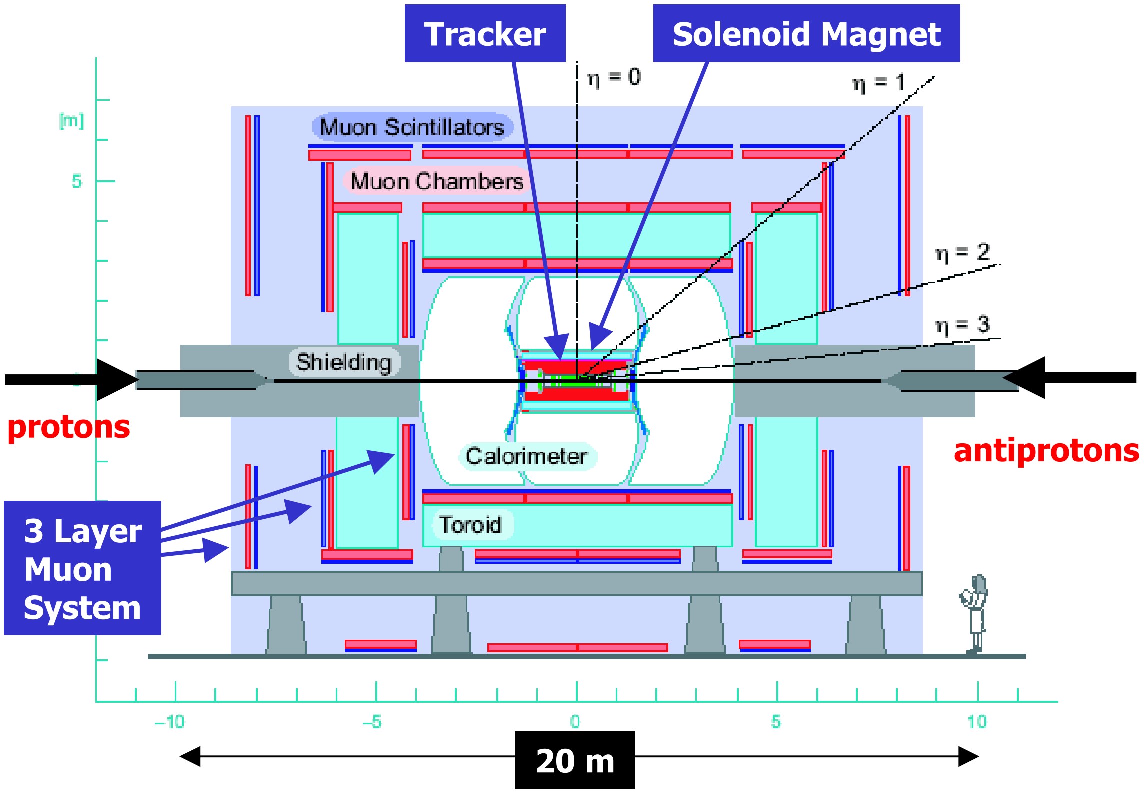
* Just added Mississippi

Physics goals

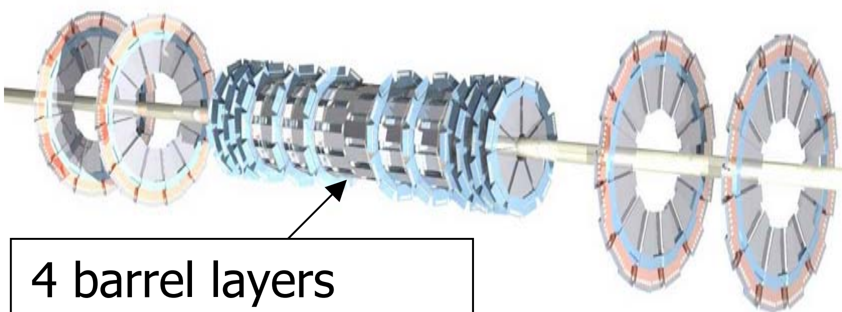
1. **Precise study of the known quanta of the Standard Model**
   - **Weak bosons, top quark, QCD, B-physics**
2. **Search for particles and forces beyond those known**
   - **Higgs, supersymmetry, extra dimensions, other new phenomena**

Driven by these goals, the detector emphasises

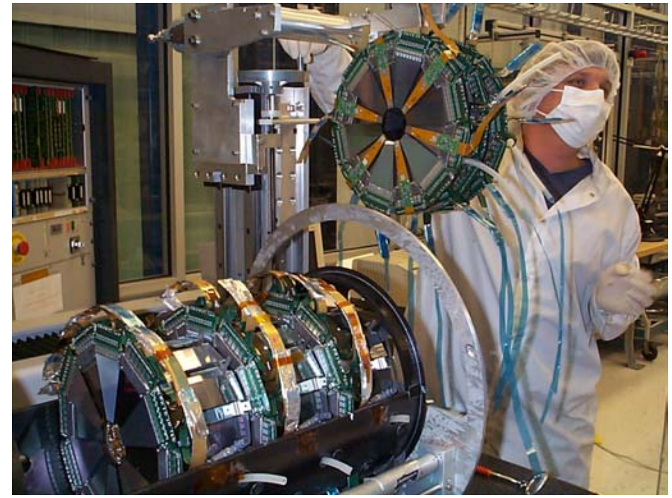
- **Electron, muon** and **tau** identification
- **Jets** and **missing transverse energy**
- **Flavor tagging** through **displaced vertices** and **leptons**

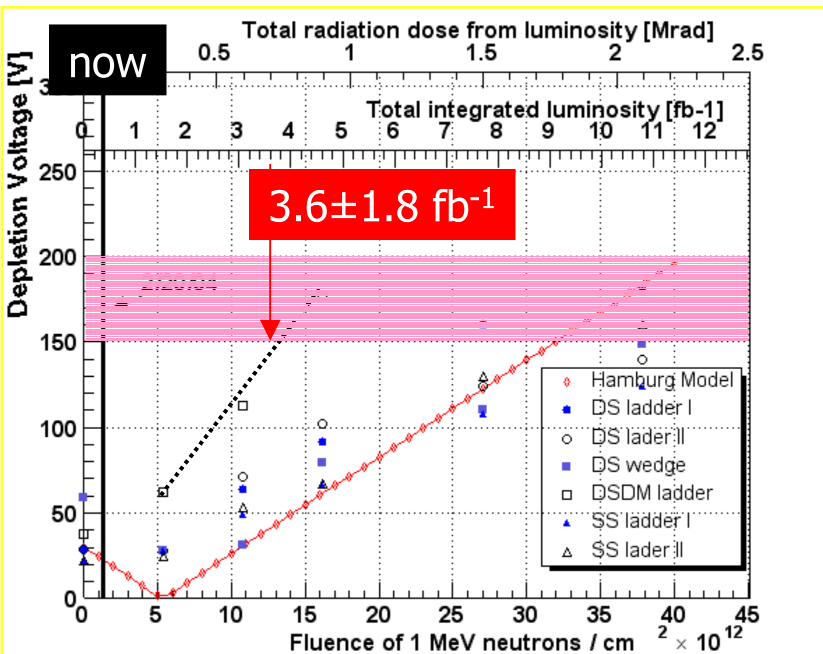


Silicon Microstrip Tracker Status



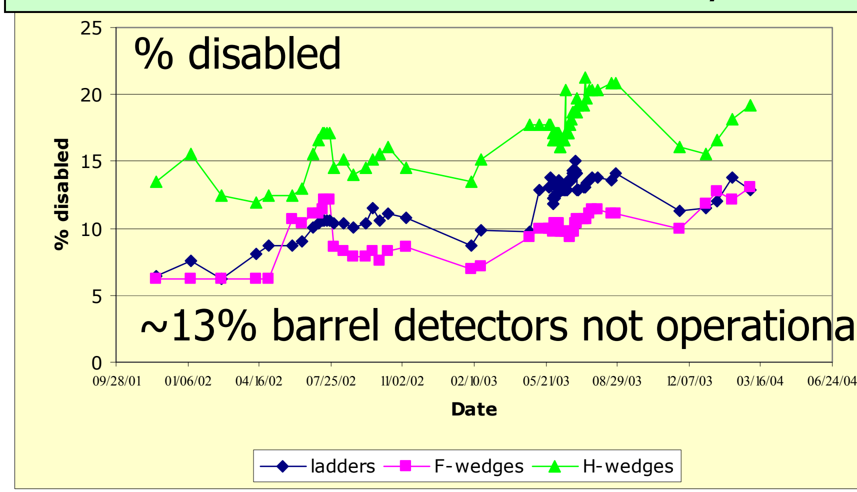
4 barrel layers
axial + stereo strips





Radiation dose and damage

Detector working very well!
There is some concern over mortality



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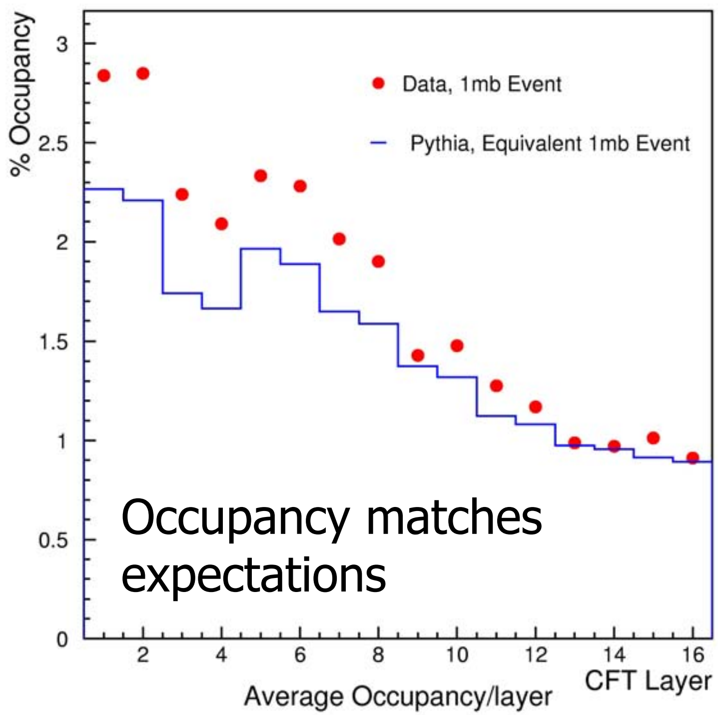
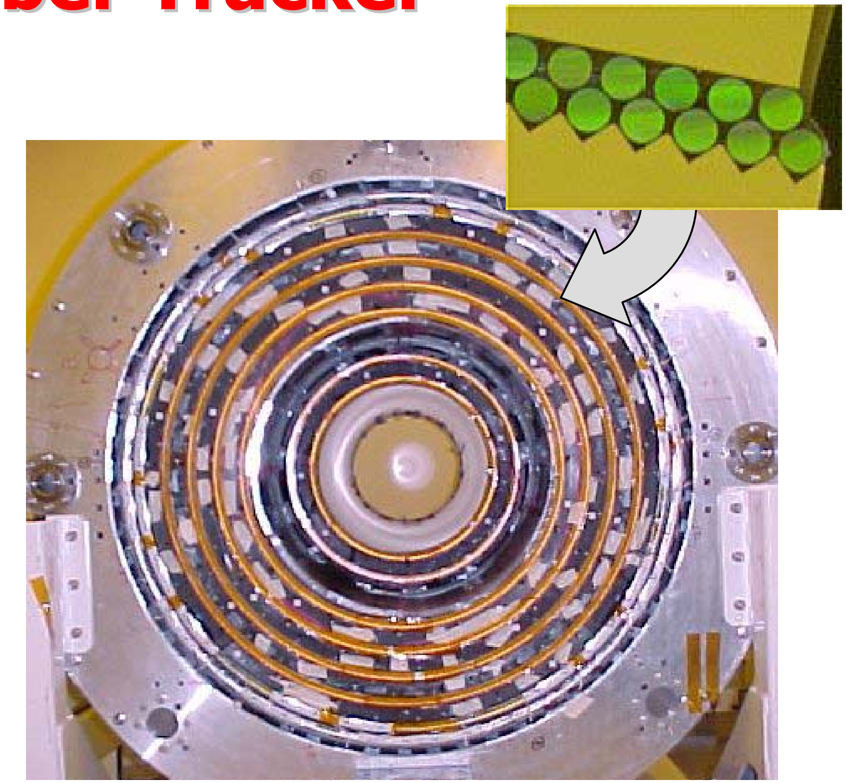
Scintillating Fiber Tracker

- **8 axial, 8 stereo layers**
- **VLPC readout**
- **Performing well**
  - **good light yield**
  - **layer ε > 98%**

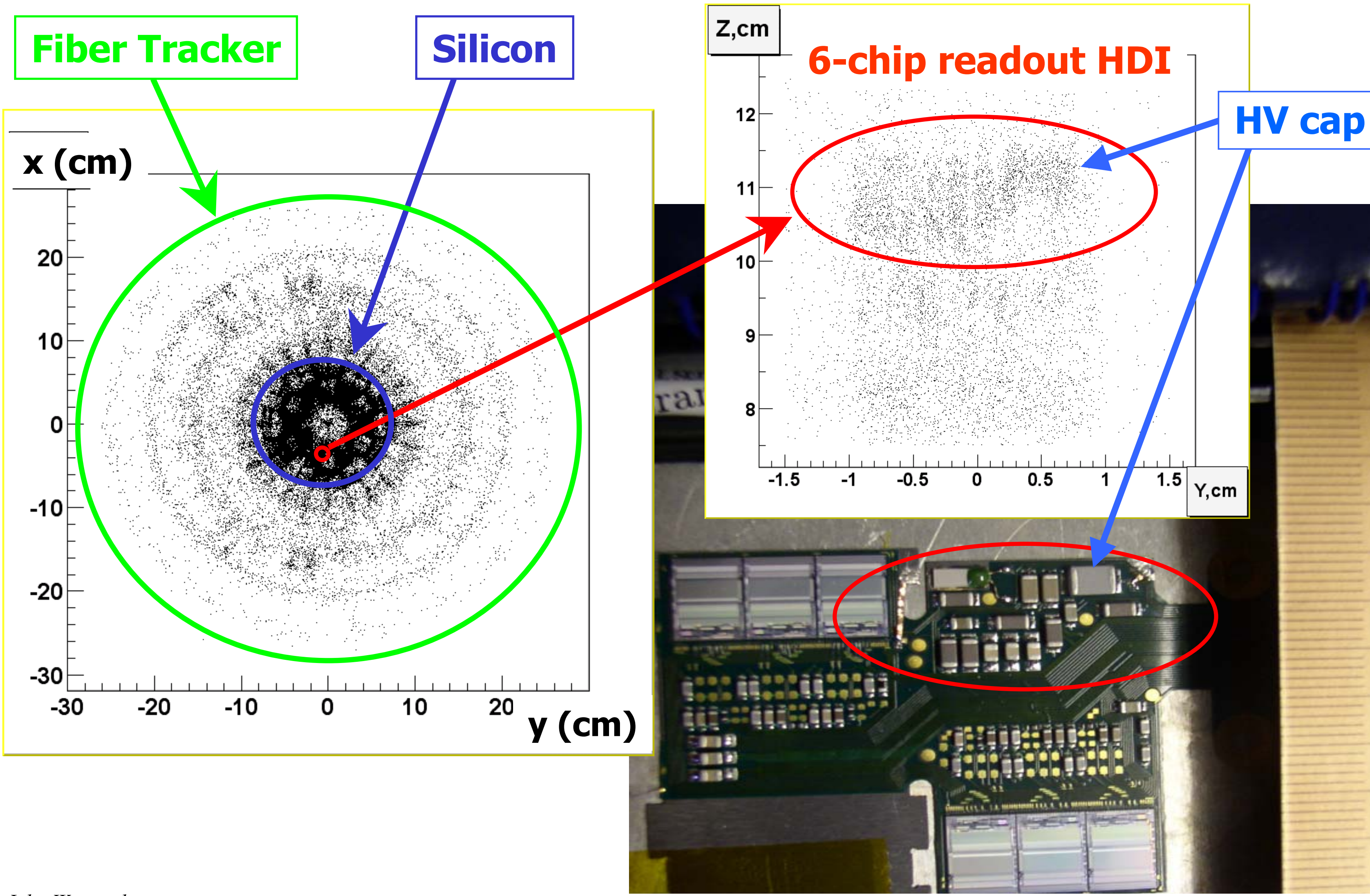
    (including dead channels)



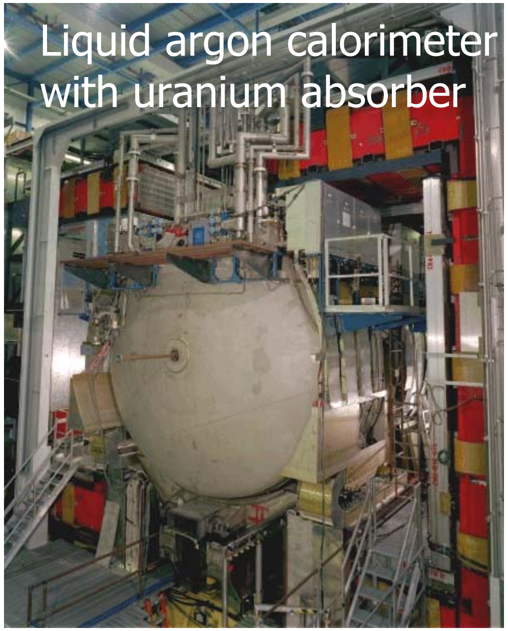


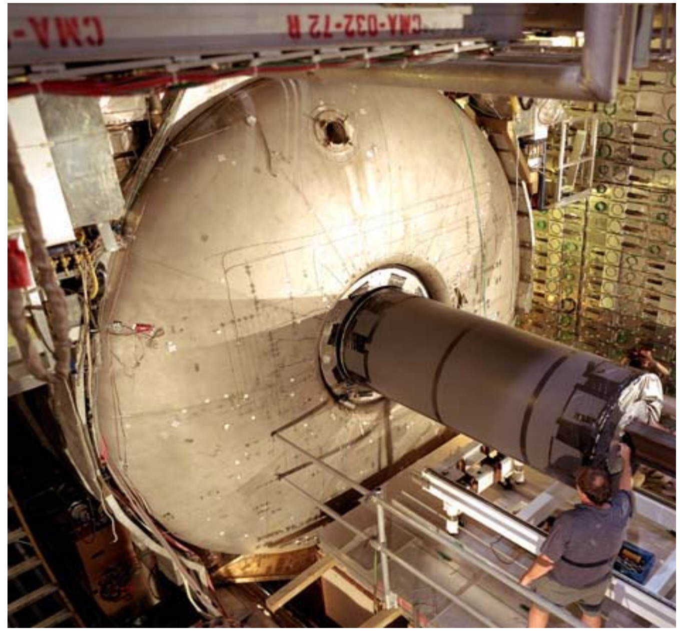
~ 1% of VLPC channels not functional since November 2003 shutdown
– a one-time event
– contamination in cryostat?

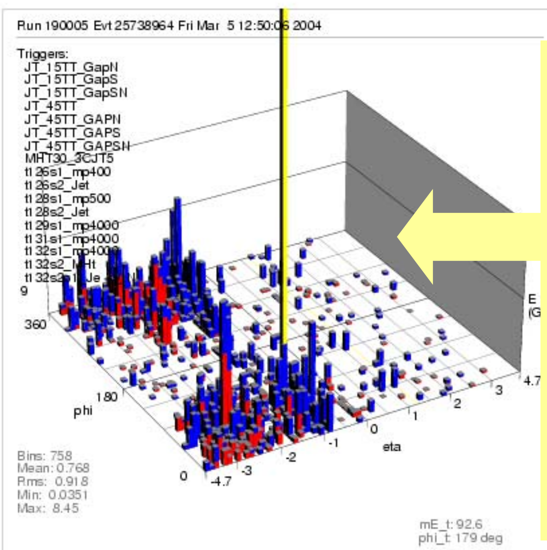
Photon Conversion "Tomography"



Calorimeter

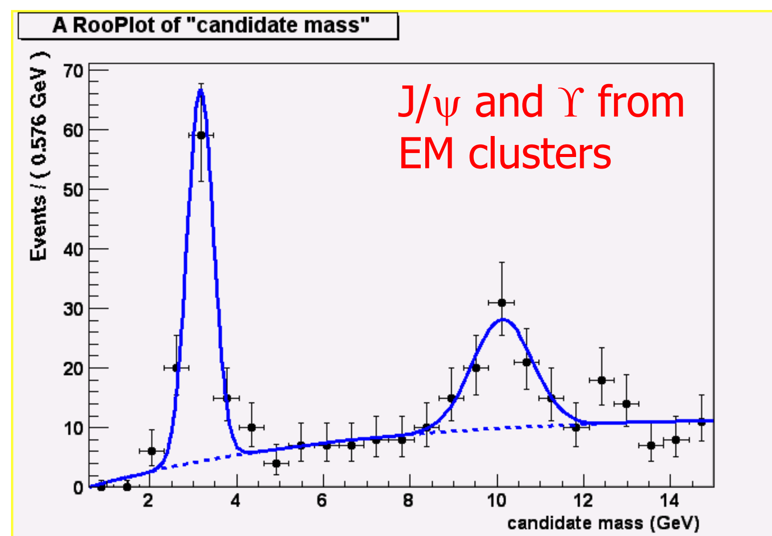






Intermittent problems with noise
– pickup from welding (2003)
– muon toroids

All OK now; still working to understand better



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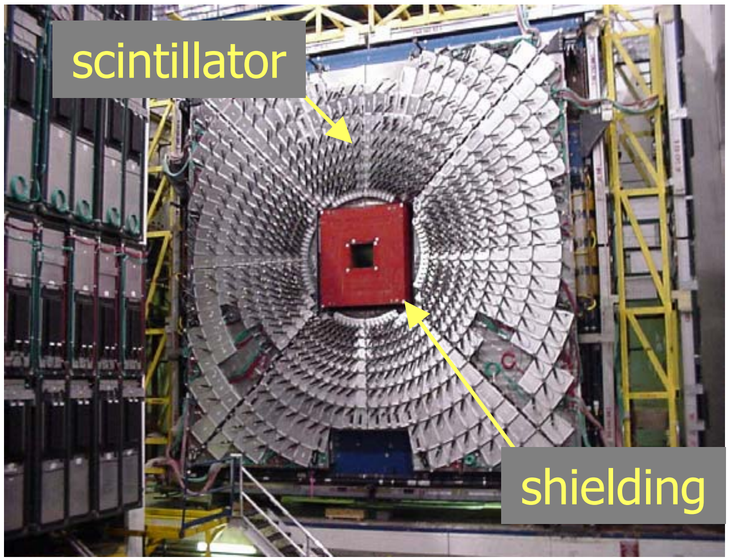
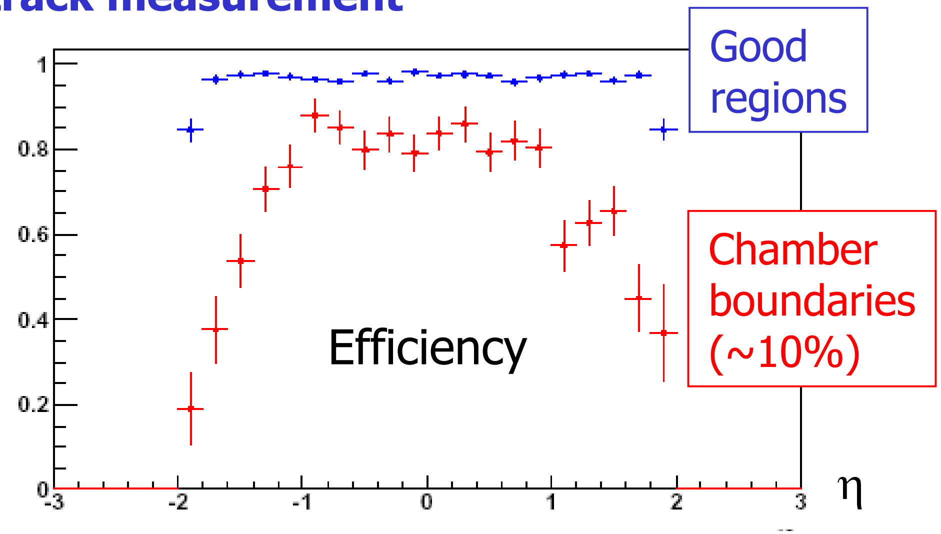
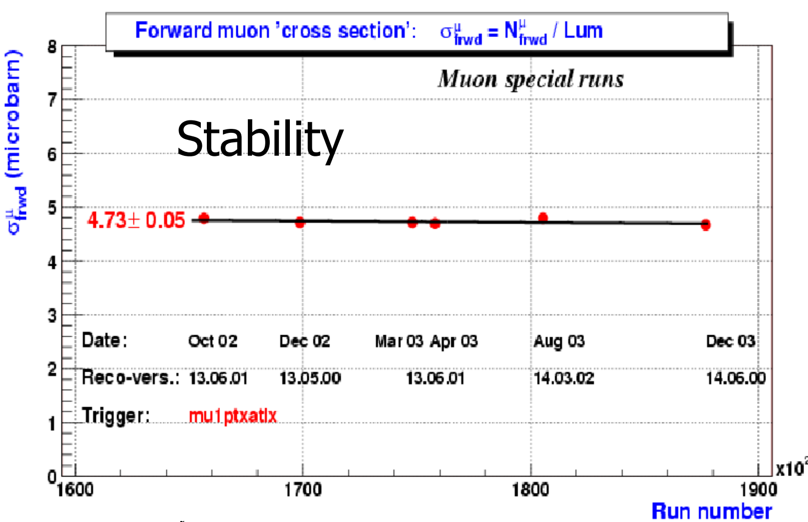
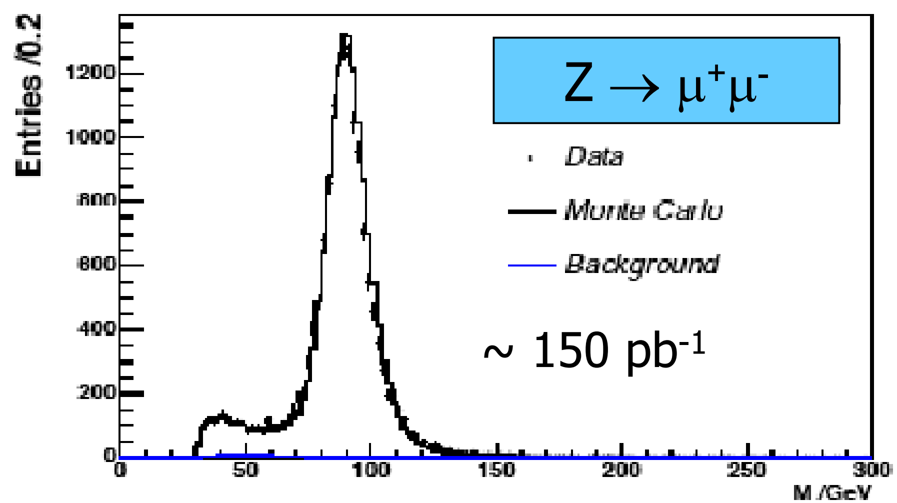
Muon System

- **Three layers of scintillator planes for triggering**
- **Three layers of drift tubes for muon track measurement**

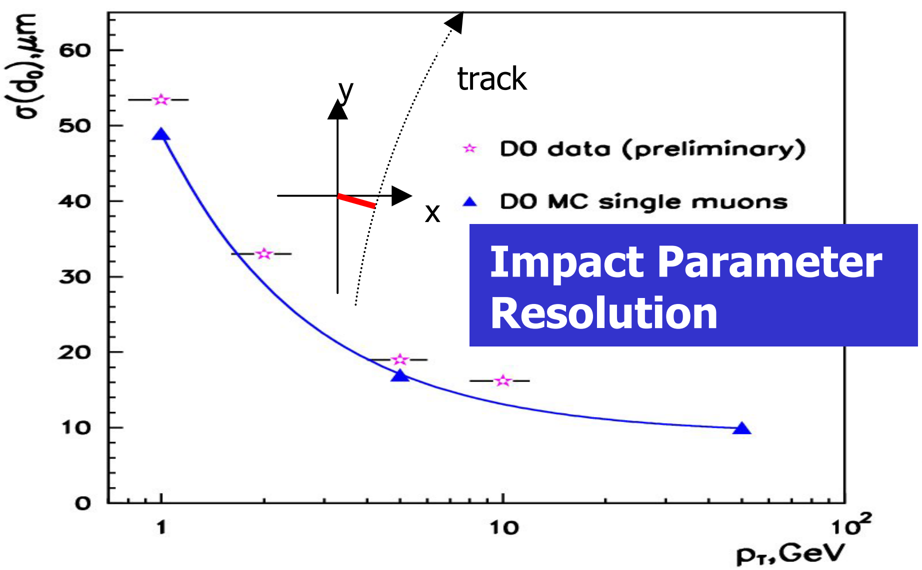


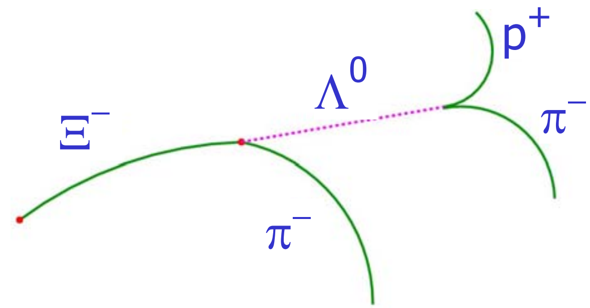


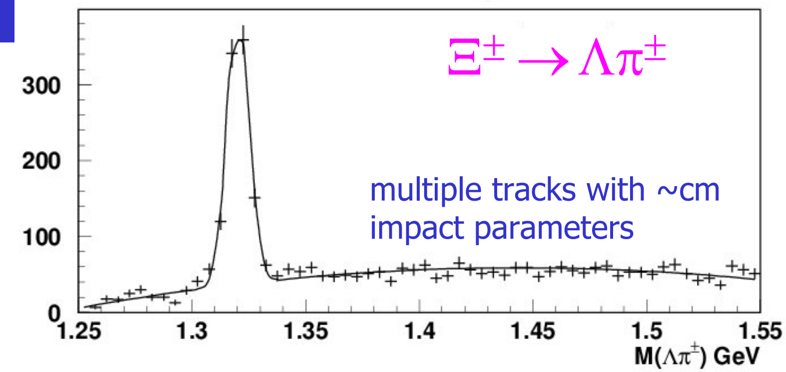




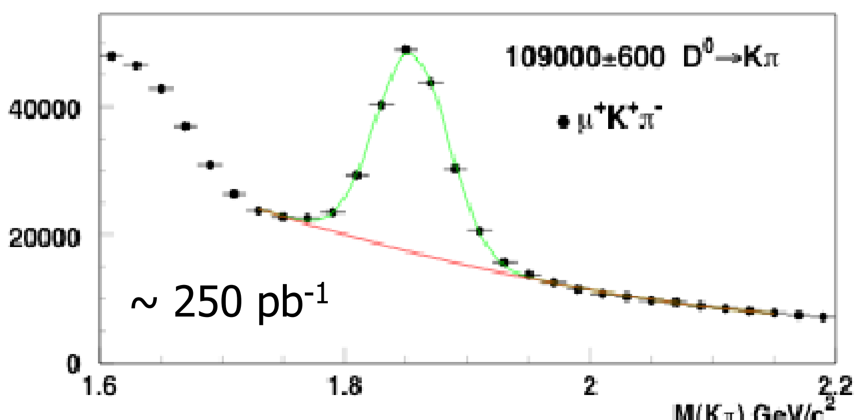
Tracking Performance

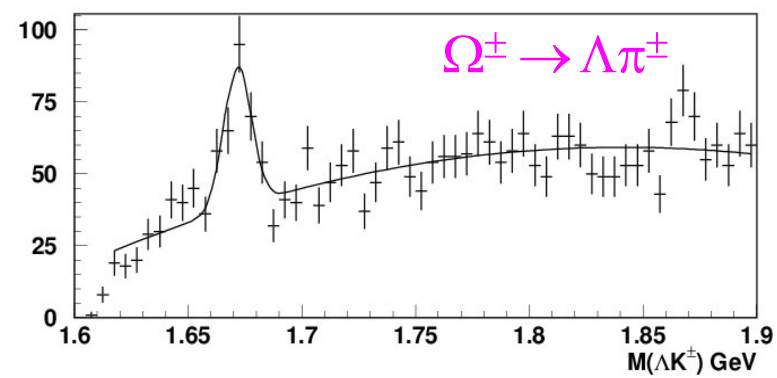






$B \rightarrow \mu\bar{\nu}D^0X$

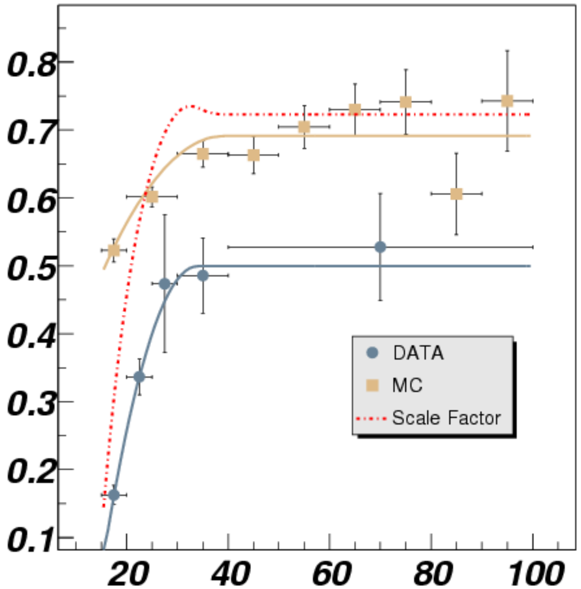




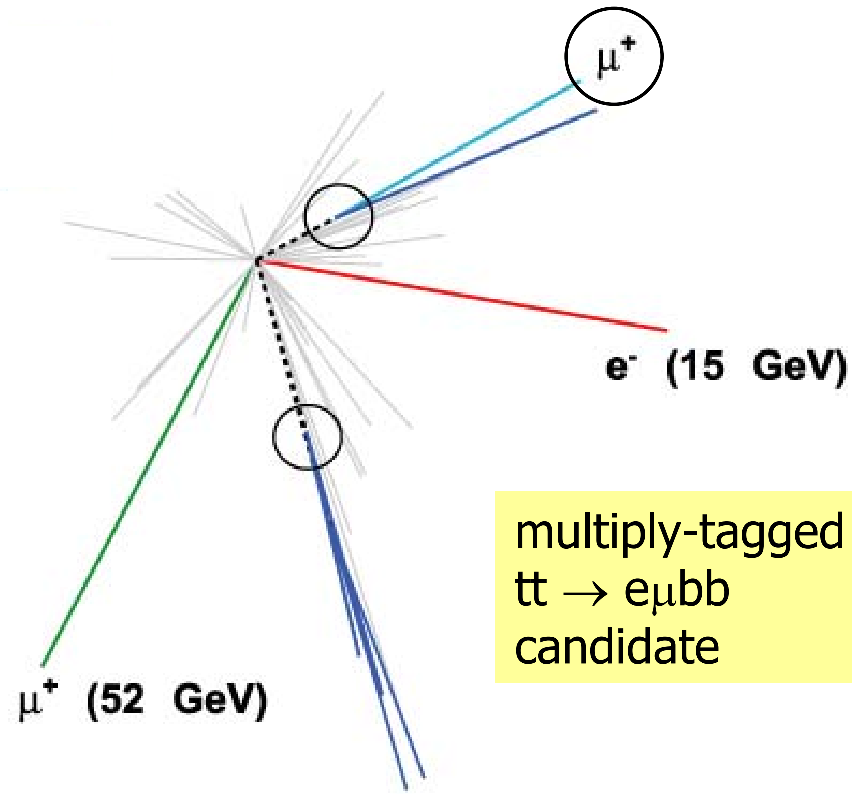
Opens new and exciting physics possibilities for DØ

b-tagging

- We have developed three independent vertex tagging algorithms, together with multiple ways of verifying their efficiencies

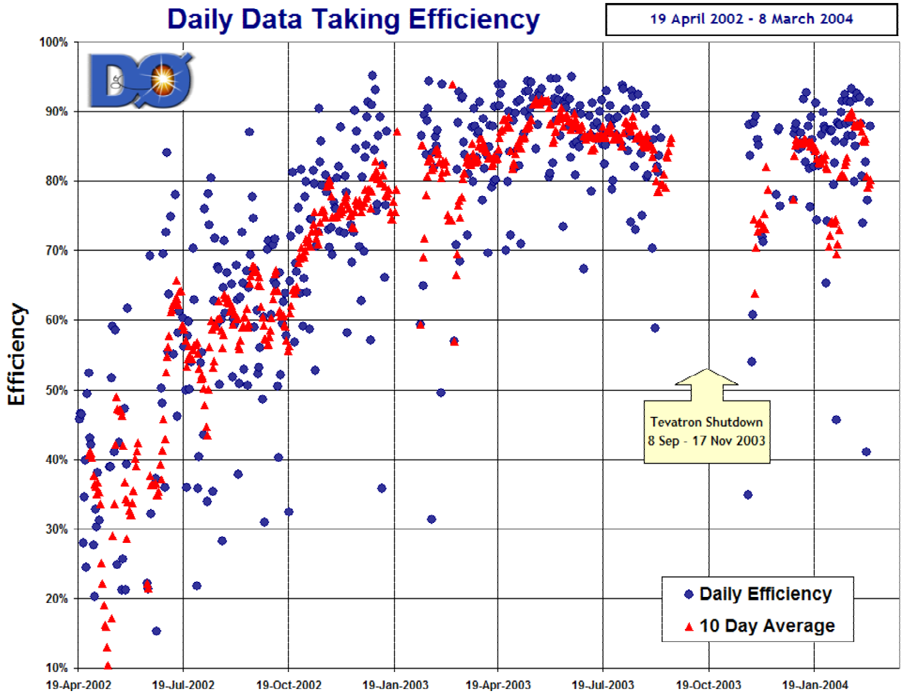


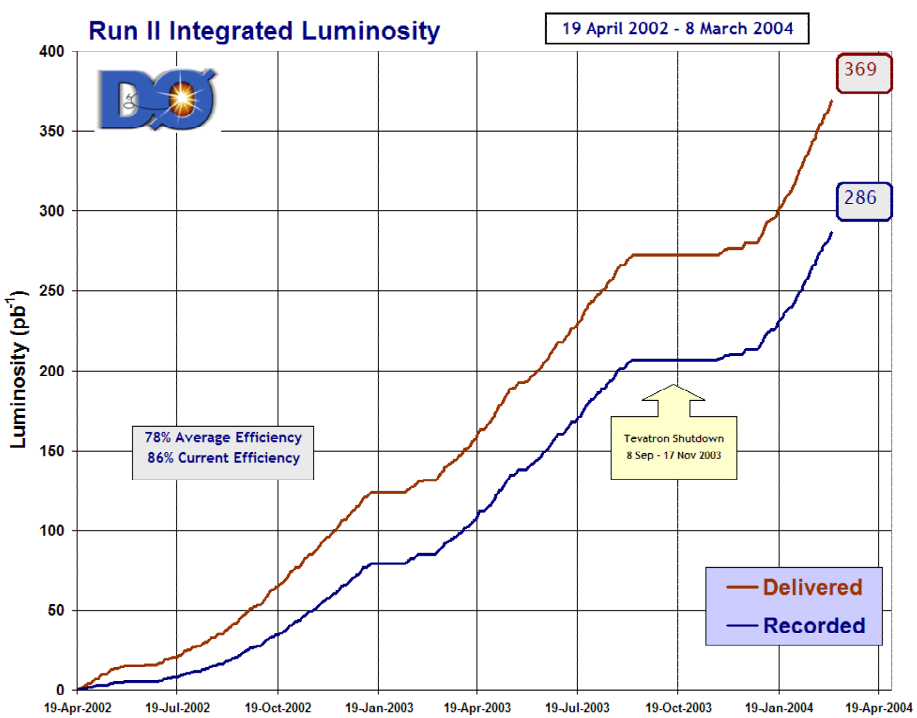
Efficiency ~ 50%
Mistag rate
(light quark jets) ~ 1-1.5%



multiply-tagged
tt $\rightarrow$ eμbb
candidate

- Also, soft lepton tagging





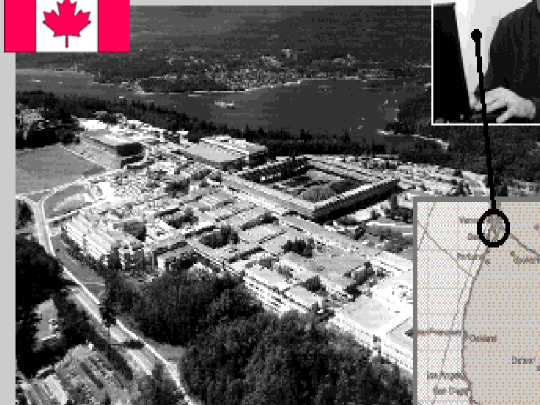
Operations

- The experiment is operating well and recording physics quality data with high (~ 90%) efficiency
  - Typical "good" day 2 pb^{-1}
  - Typical "good" week 10 pb^{-1}
    - = Run Ia in a week
  - We will soon install an updated trigger list for higher luminosities
- Data are being reconstructed on the Fermilab farm within a few days
- > 280 pb^{-1} on tape
- 150-250 pb^{-1} being used in current physics analyses
- DØ computing systems served up 0.25PB of data, 8 billion events for analysis just in the last couple of months

Our congratulations – and thanks – both to the Accelerator Division and the Computing Division

DZero

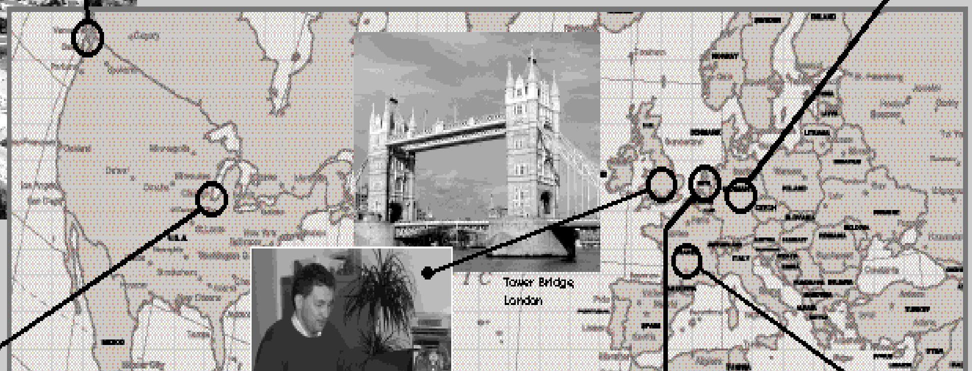
"You can't make the Grid work without motivation. It's one thing to have a vision, and it is another thing to stay up to three in the morning to make things work because they need to get done. DZero is a real application. We need to get the physics results out."
– Dugan O'Neil, Simon Fraser University, Canada



SFU campus on Burnaby Mountain, Vancouver

Wuppertal's landmark, the elevated train line

"In the past, particle physics collaborations have used remote computing sites to carry out Monte Carlo simulations. We are now one of the first experiments to process real data at remote sites. The effort has opened up many new computing resources. The evaluation of our experience will provide valuable input to the Grid development."
– Daniel Wicke, University of Wuppertal, Germany



Tower Bridge
London

"The machines at Imperial College, for example, are shared across the whole college, so it takes grid software to keep it all running smoothly." – Gavin Davies, Imperial College London, UK

Street scene in Lyon

"We've participated in large-scale Monte Carlo production in the past, but data reprocessing involves large volumes of data to be transferred in both directions on a scale that was simply unthinkable a few years ago. It will open new possibilities that we are only beginning to explore."
– Patrice Lebrun (right), with Tibor Kurca, CCIN2P3, Lyon, France

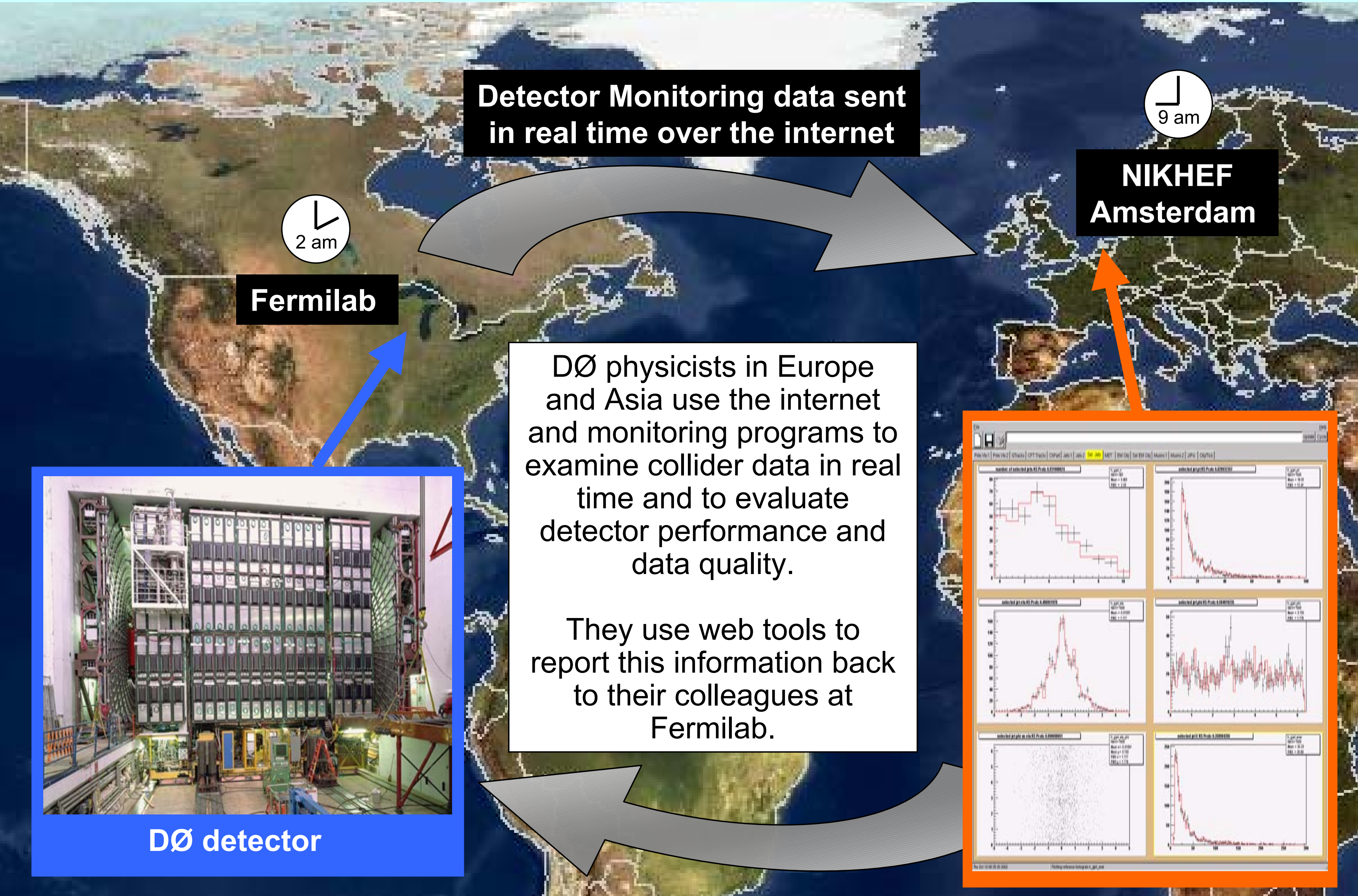
"With the SAM software developed by the Fermilab Computing Division and DZero, a user doesn't know whether the data is stored on tape or on disk, whether it is located at Fermilab or at Karlsruhe."
– Wyatt Merritt (left), with Mike Diesburg and Amber Boehnlein, Fermilab, U.S.A.

Amsterdam, famous for its canals

"The re-processing was a major milestone for DZero. For us it is also important that we have been able to show that we can really use the LHC Computing Grid for DZero processing. We saw jobs submitted from Wuppertal being executed on our CPUs, and we executed jobs in Karlsruhe, at Rutherford Appleton Laboratory and a few more places."
– Kors Bos (front row, second from left) and the Scientific Computing team at NIKHEF, Amsterdam, Netherlands

Autumn 2003
~ 200 pb^{-1} of data reprocessed
Worldwide effort, exploiting Grid resources

Remote International Monitoring for the DØ Experiment



All daytime monitoring shifts are now being run from **Brazil**

Our Physics Goals

- Confront the Standard Model through
  - 1. The strong interaction
  - 2. The CKM matrix
  - 3. Precision electroweak tests
  - 4. The top quark
  - 5. The Higgs boson

- And directly search for new phenomena not part of the SM

<u>Current status</u>

- Reprocessed 200pb^{-1} of data last fall – greatly improved tracking
- ~ 40 analyses in review
- Hope to be showing lots of new results soon
  - Alas, not all approved in time for this talk
- First Run II PRL paper is in review

Winter Physics Workshop (February 22nd 2004) - Netscape

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http://www-d0.hef.kun.nl/fullAgenda.php?ida=a04273

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Winter Physics Workshop

Date/Time: from Sunday 22 February 2004 (09:00) to Tuesday 24 February 2004 (18:00)

Location: FNAL

Room: One West

Chair: Ursula Bassler, Flera Rizatdinova , Chris Tully

Description: *video-streaming from: http://www-visualmedia.fnal.gov/real/DzeroWorkshop/index.htm*

[last update: Wednesday 25 February 2004]

Sunday 22 February 2004 10:00->12:00	introduction & overview (One West)	Ursula Bassler
Sunday 22 February 2004 13:30->18:30	electrons, photons and missing Et (One West)	Drew Alton (1st half) Slava Kulik (2nd half)
Monday 23 February 2004 09:00->12:00	jets (One West)	Nirmalya Parua
Monday 23 February 2004 13:30->15:30	muons (One West)	Frederic Deliot
Monday 23 February 2004 16:00->18:00	physics with b tags (One West)	Gordon Watts
Tuesday 24 February 2004 09:00->12:00	physics with tracks (Auditorium)	Mike Hildreth
Tuesday 24 February 2004 13:30->14:00	simulation (Auditorium)	Chris Tully
Tuesday 24 February 2004 14:00->16:00	muons cont'd (Auditorium)	Chris Tully
Tuesday 24 February 2004 16:00->18:20	improvements, prospectives and plans (Auditorium)	Flera Rizatdinova

Sunday 22 February 2004

introduction & overview (10:00->12:00)

Chair: Ursula Bassler
Room: One West

10:00	**Workshop Goals** (15') (transparencies)	**Jianming Qian**
10:15	**D0Reco - status/plans** (15') (transparencies)	**Suyong Choi**
10:30	**Datasets - CSG report** (30') (transparencies)	**Marco Verzocchi**
11:00	**Data Quality - muons** (15') (transparencies)	**Tom Diehl**
11:15	**Data Quality - Calorimeter** (15') (transparencies)	**Slava Shary**
11:30	**Data Quality - Calorimeter jet/met** (15') (transparencies)	**Gregorio Bernardi**
11:45	**Data Quality - Tracking** (15') (transparencies)	**Michael Weber**

electrons, photons and missing Et (13:30->18:30)

Chair: Drew Alton (1st half) Slava Kulik (2nd half)
Room: One West

13:30	**Electron + Photon identification** (15') (transparencies)	**Jan Stark**
13:45	**Missing Et** (15') (transparencies)	**Patrice Verdier**

QCD

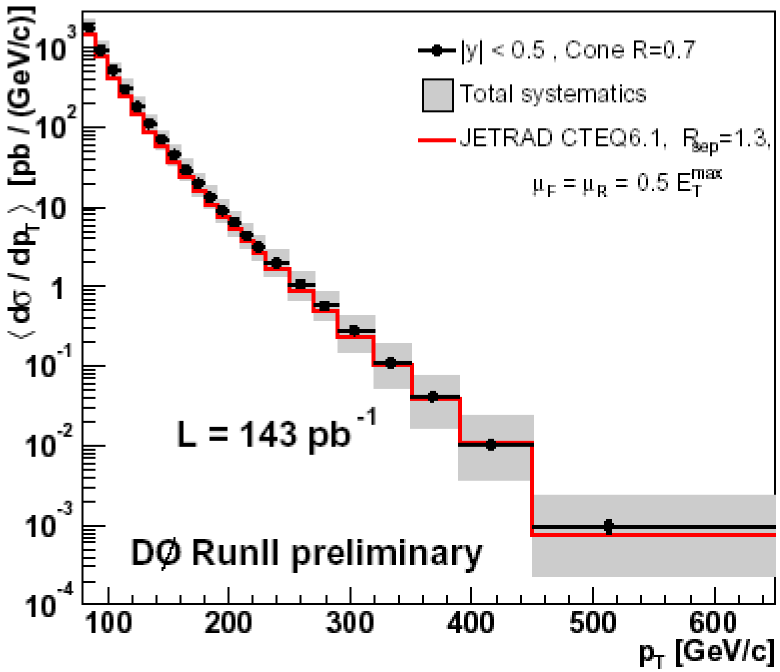
<u>We need to:</u>

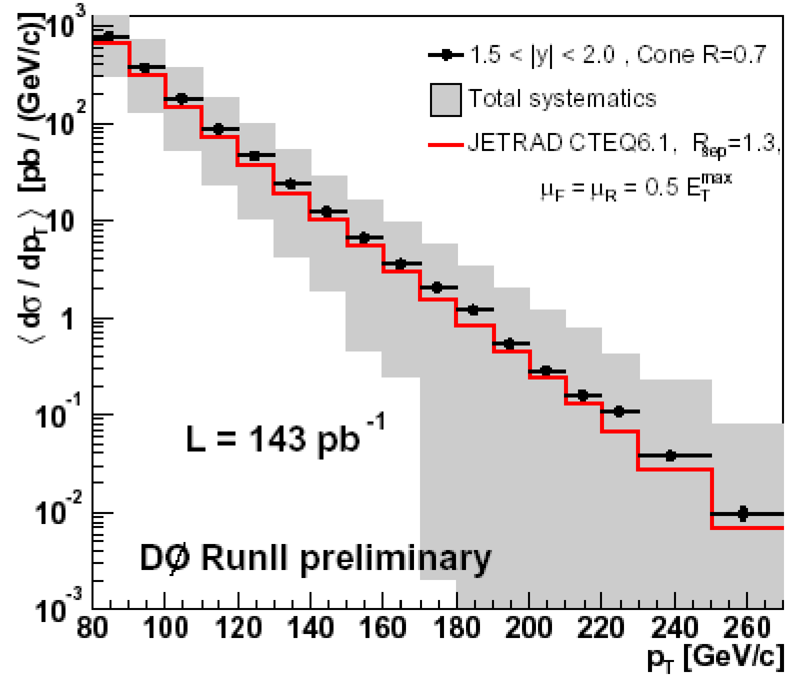
Use well-understood processes to measure proton structure

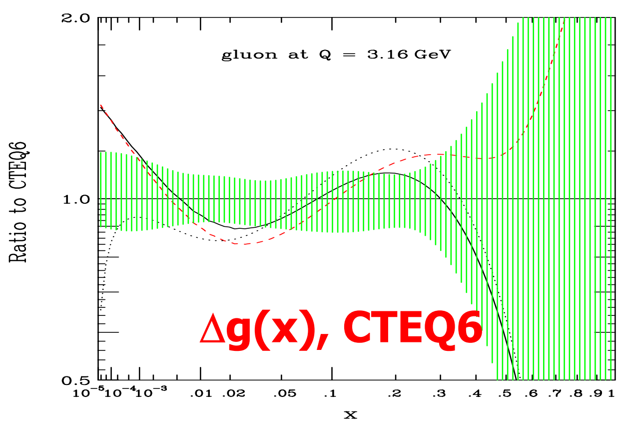
Resolve some outstanding puzzles
e.g. heavy flavour production, hard diffraction

Understand the backgrounds to new physics

Jet cross sections







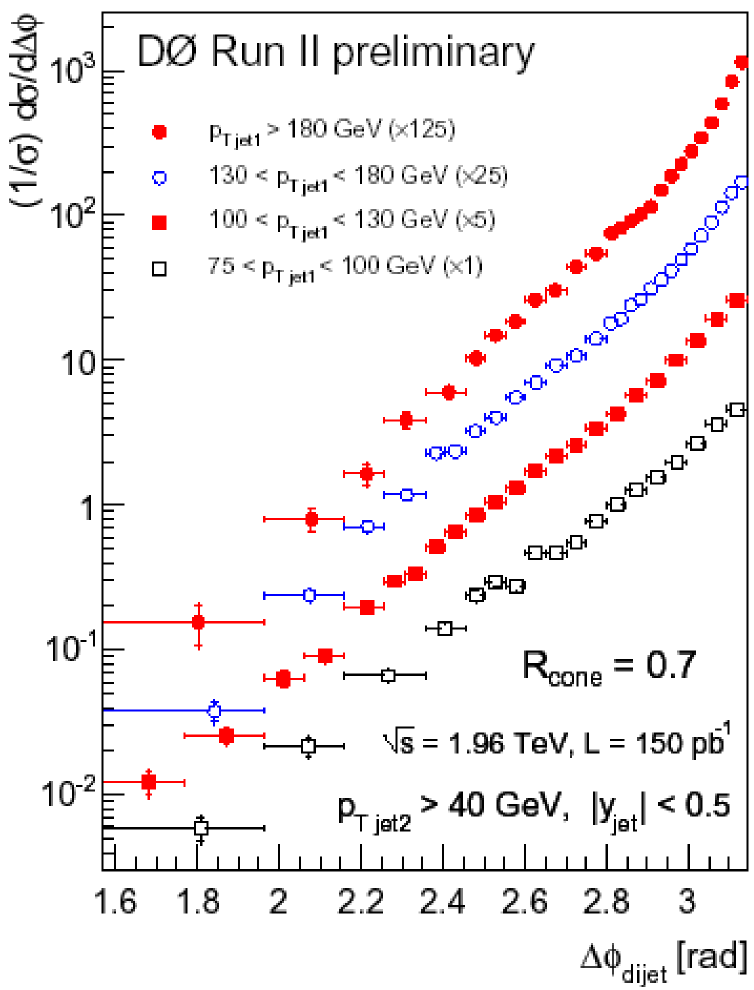
High p_T jets constrain the gluon content of the proton

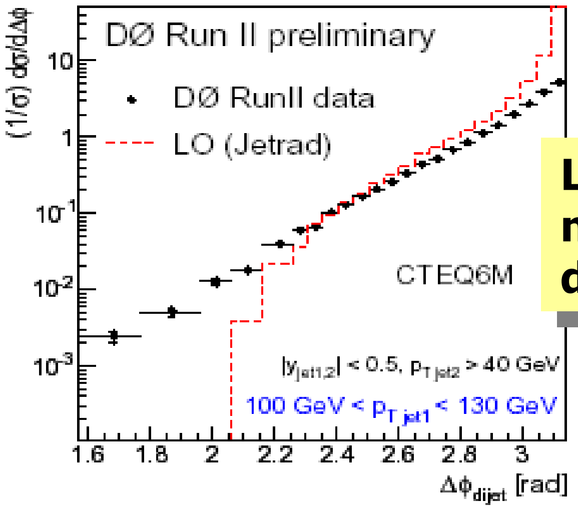
Still working hard to reduce the dominant uncertainty: the jet energy scale

- **derived from p_T balance in photon + jet events**

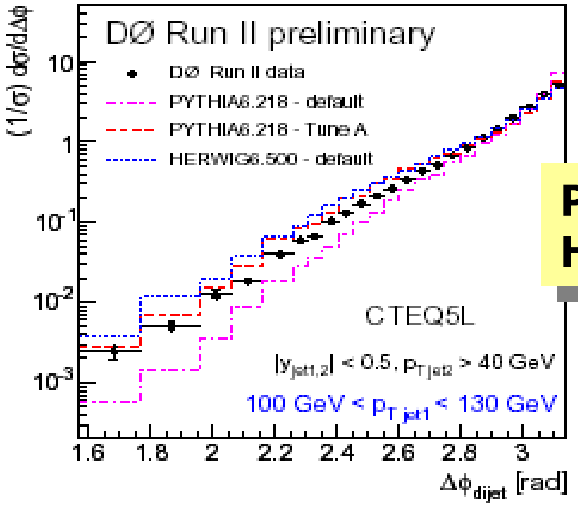
Dijet angular distributions

- **Compare with LO QCD and with parton shower Monte Carlo generators**





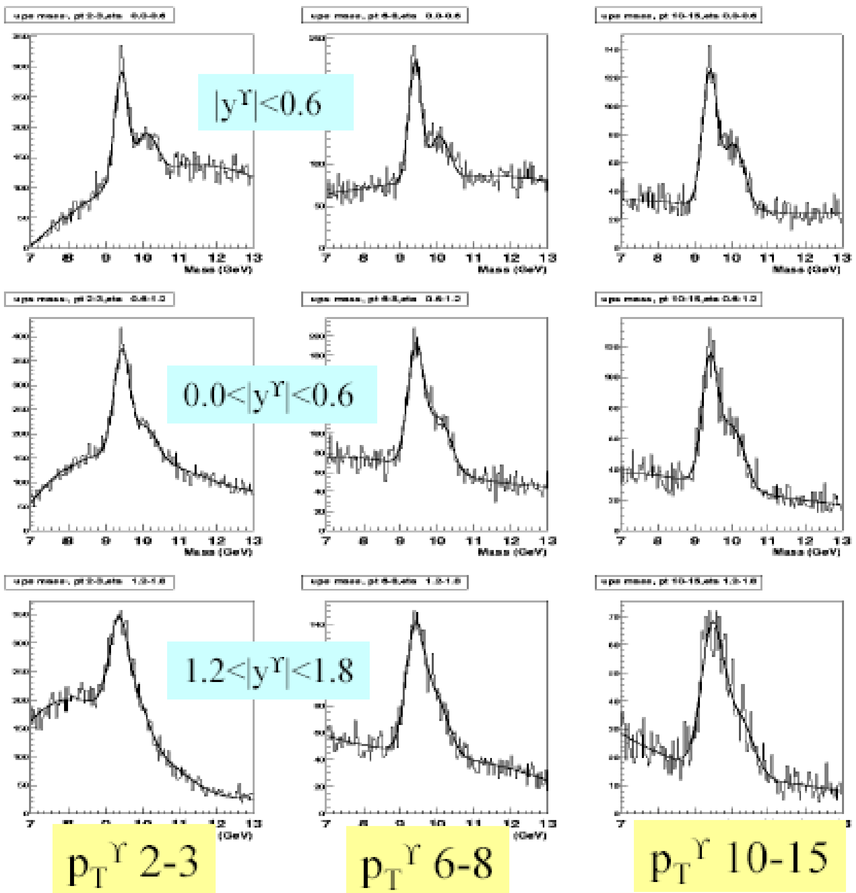
LO QCD not a good description



PYTHIA & HERWIG

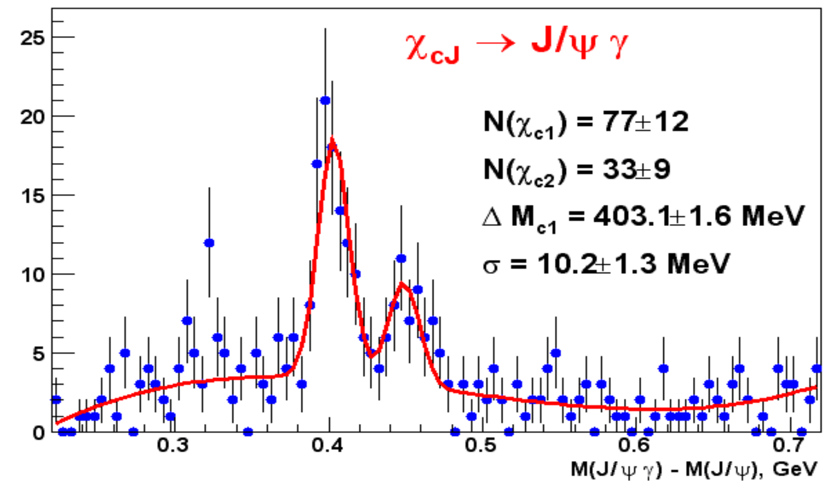
Heavy flavour production

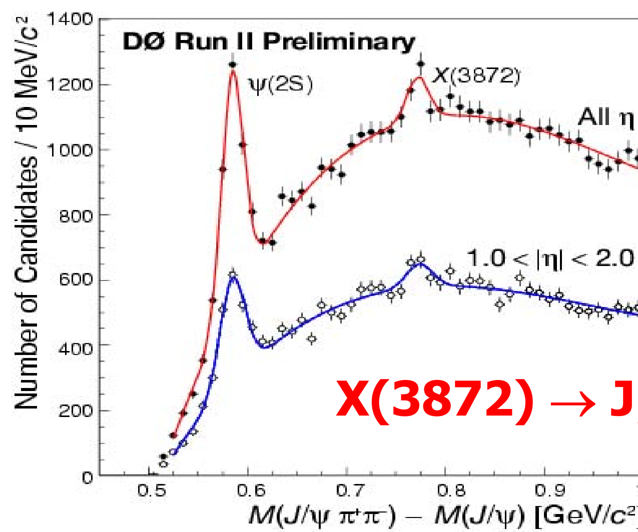
Upsilon $\rightarrow \mu^+\mu^-$



~ 160 pb^{-1}

Charmonium



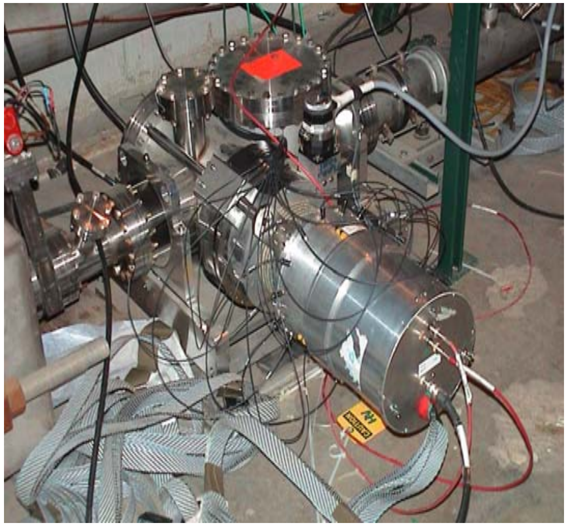


~ 250 pb^{-1}

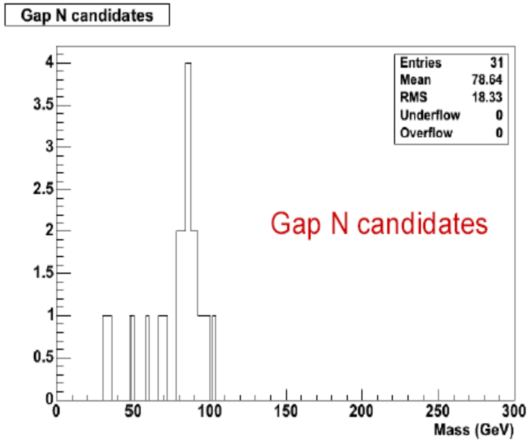
X(3872) $\rightarrow$ J/$\psi\ \pi^+\pi^-$

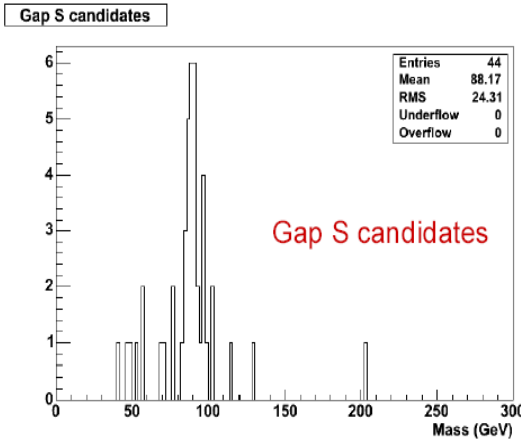
Hard diffraction

- **How can we produce a high mass state like a W or Z and yet leave one of the beam particles intact?**
- **New instrumentation for Run II:**
  - **FPD (Roman pots at $z = \pm$ 23, 33, 57, 59m)**
  - **veto counters to cover $2.5 < |\eta| < 6$**



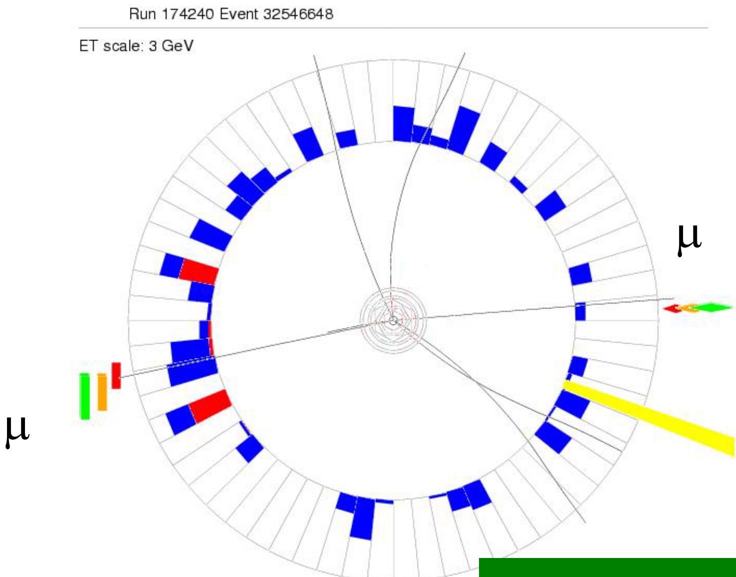
- **Diffractive Z analysis now underway using both rapidity gaps and FPD**
  - **Relate rapidity gaps to diffractive (anti-)protons seen in Roman Pots**
  - **Measure the “gap survival probability”**



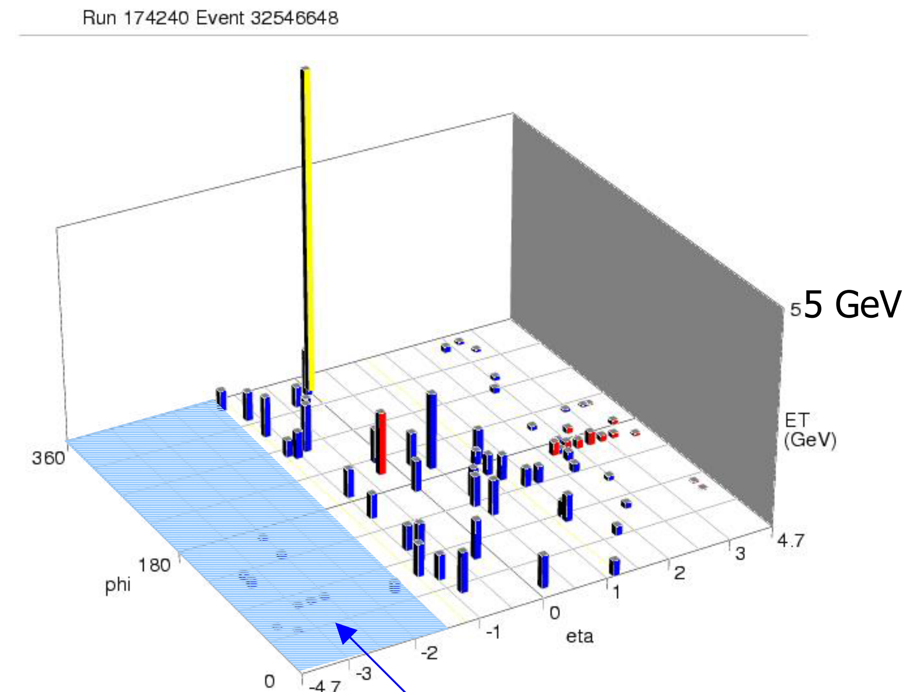


Z ($\rightarrow \mu\mu$) produced with a rapidity gap

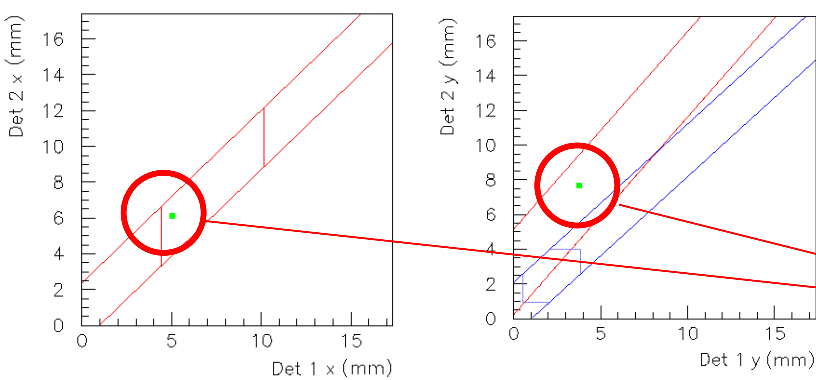
Diffractive Z Candidate



Z → μμ event



...with rapidity gap



... and coincident hits in the FPD detector

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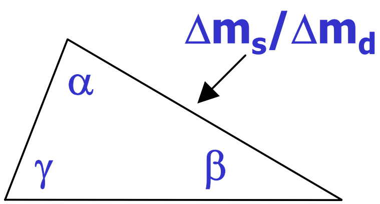
CKM Physics

Confront the unitarity triangle in ways that complement measurements at the e^+e^- B-factories
e.g. through the B^0_s system . . .



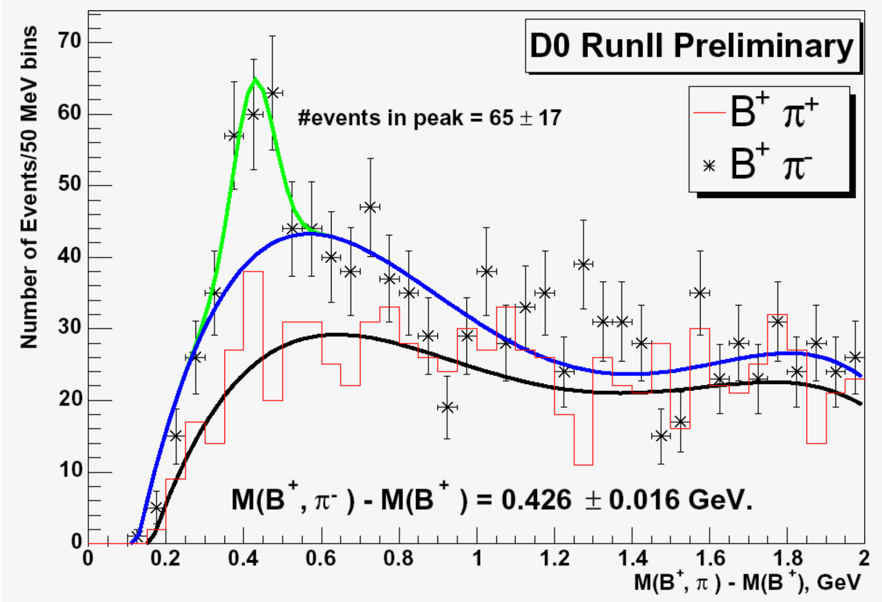
Also, can measure V_{tb} through single top production

Putting the tools in place

DØ does not exploit purely hadronic triggers, but benefits from large muon acceptance, forward tracking coverage, and ability to make use of $J/\psi \rightarrow e^+e^-$

- **J/ψ, ϕ, K … reconstruction**

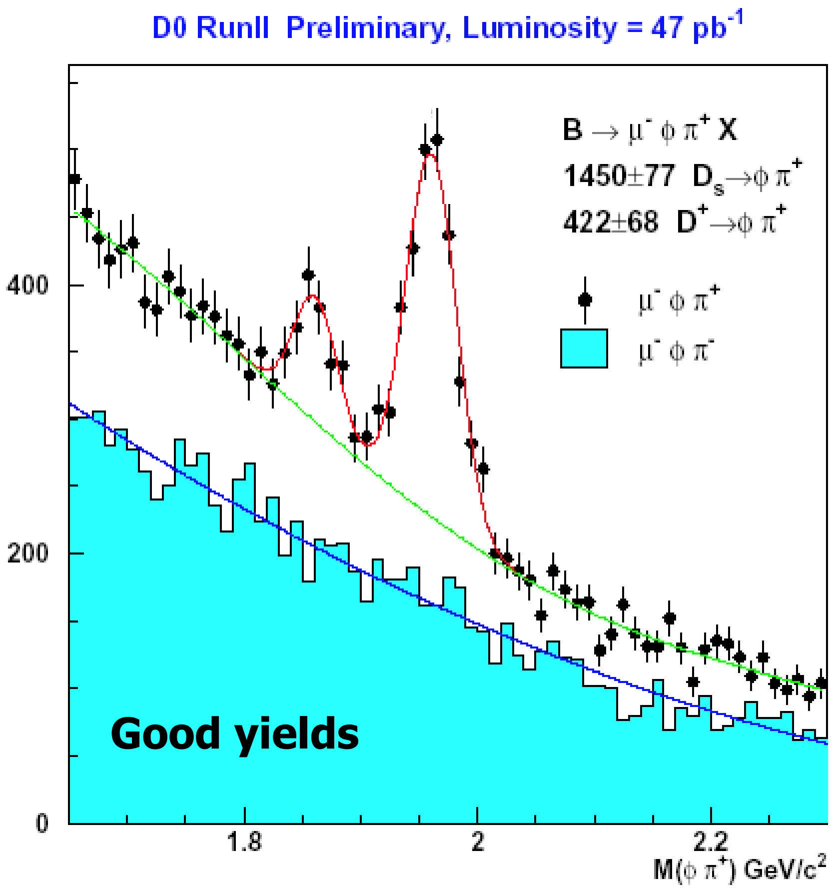
$B_d^{**} \rightarrow B^{\pm}\pi$



- **B tagging - muons, electrons, displaced vertices**
- **Flavor tagging - estimates from $B^{\pm} \rightarrow J/\psi\ K^{\pm}$**
  - **Opposite side jet charge tagging power $\varepsilon D^2 = 3.3 \pm 1.1\%$**
  - **Opposite side soft muon tagging power $\varepsilon D^2 = 1.6 \pm 0.6\%$**

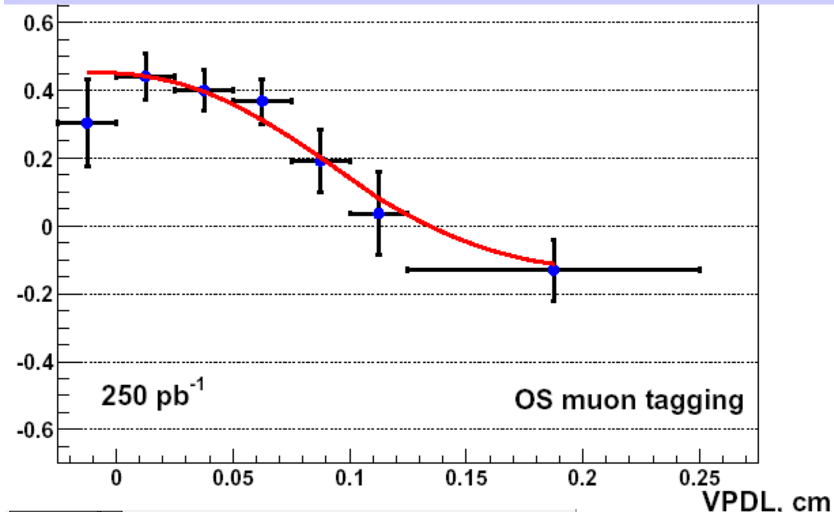
Towards a B_s Mixing Measurement

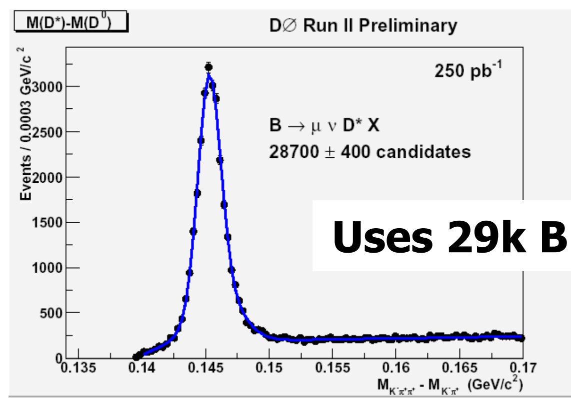
- $B_s \rightarrow D_s\, \mu + X$



- B_d oscillations

$A = (N_{non\text{-}osc} - N_{osc})/(N_{non\text{-}osc} + N_{osc})$





Uses 29k $B \rightarrow D^* \mu\nu + X$

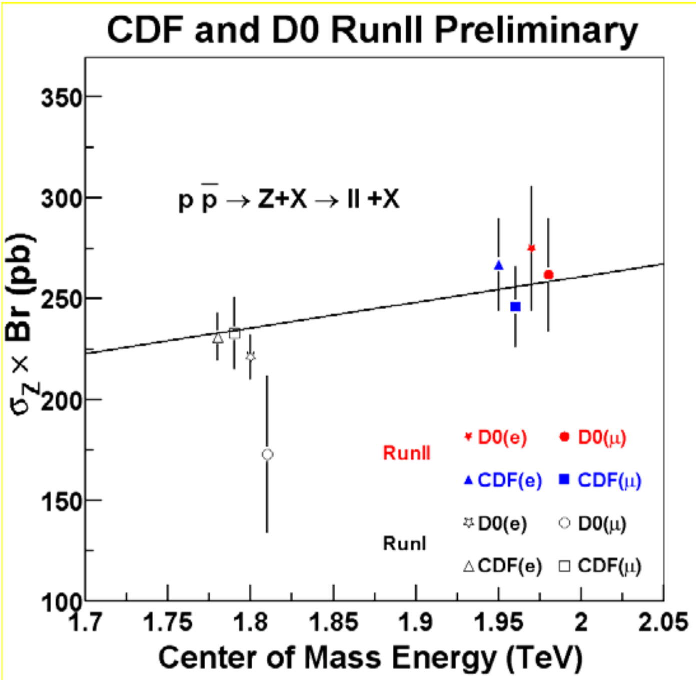
John Womersley

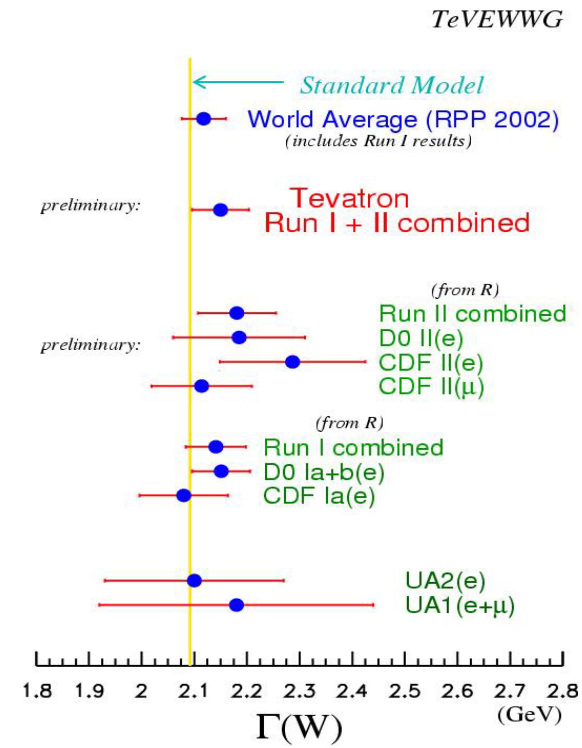
Electroweak Physics

Indirectly constrain new physics through precision measurements of electroweak parameters, especially m_W

Also measure forward-backward asymmetry in Z production, multiboson production, boson + jets, …

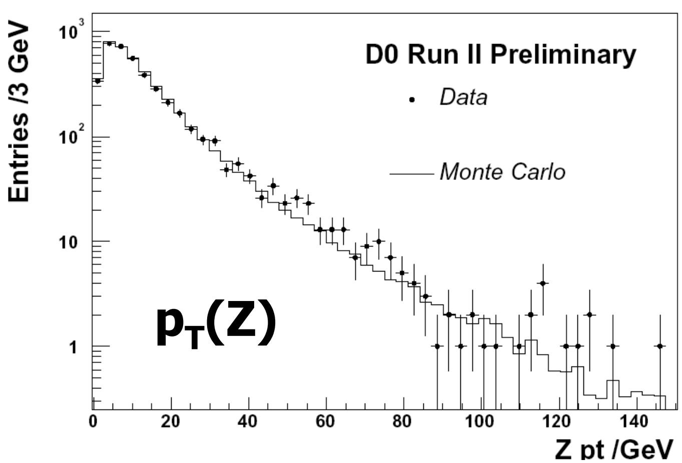
W and Z production

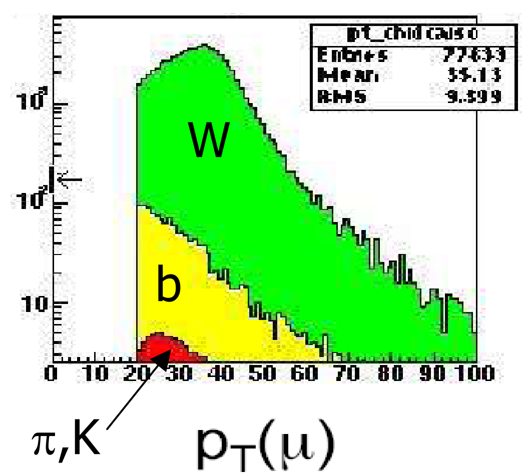




Indirect W width

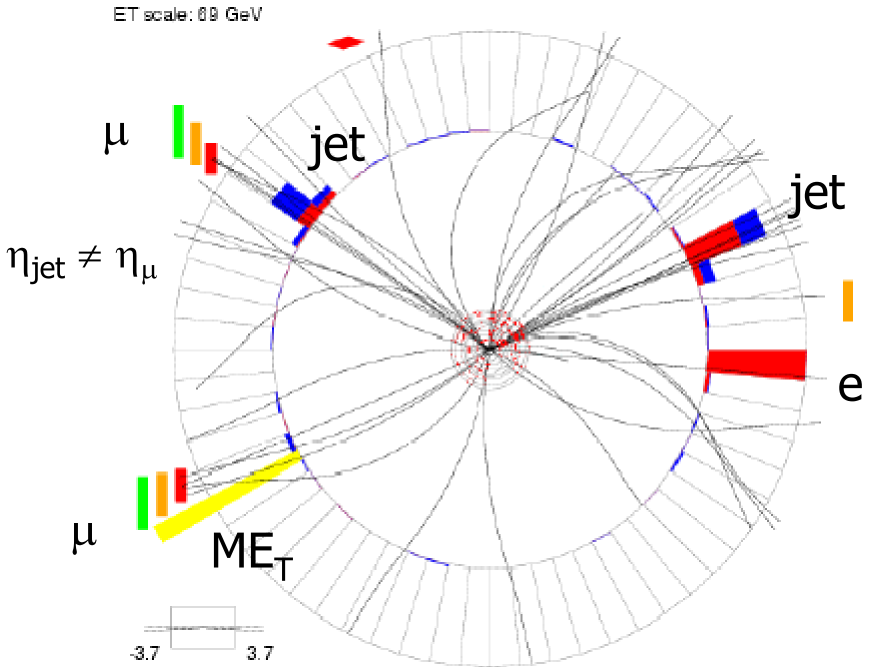
First result from new Tevatron EWWG

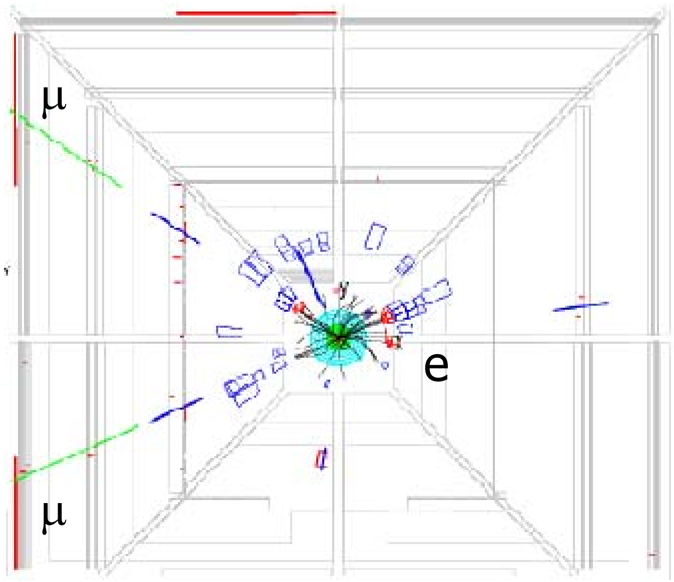




W $\rightarrow \mu\nu$
Working on a detailed understanding of backgrounds;
Prelude to m_W

WZ production





- **See 2 candidates in e$\mu\mu$ and 1 in $\mu\mu\mu$**
  - **Rate roughly consistent with SM**

Wγ analysis also in progress

The Top Quark

The Tevatron Collider is the world's <u>only source of top quarks</u>

Top couples strongly to the Higgs field:
offers a window on fermion mass generation

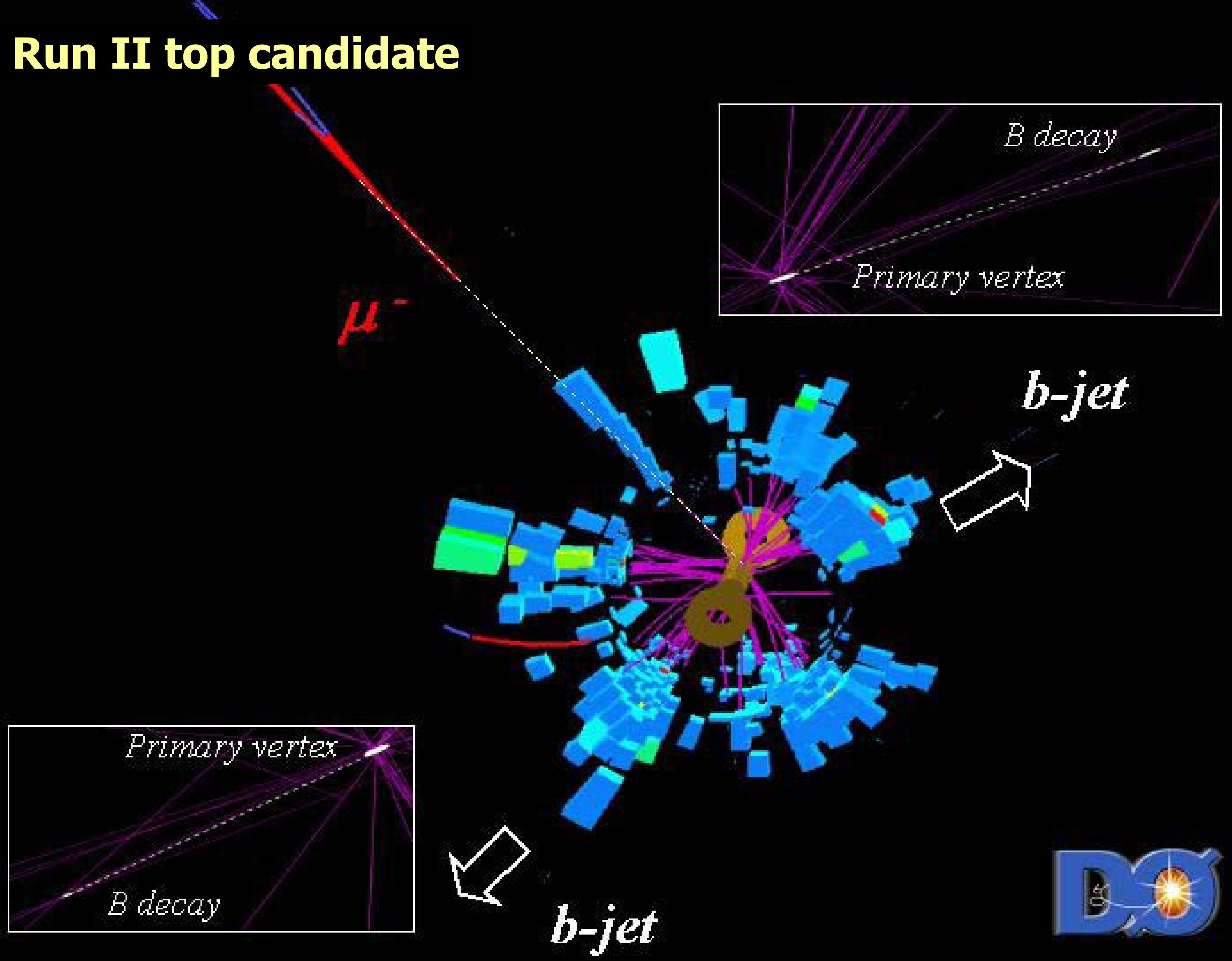
<u>We need to:</u>

Measure its properties with greatly increased statistics

- the top mass constrains the Higgs sector

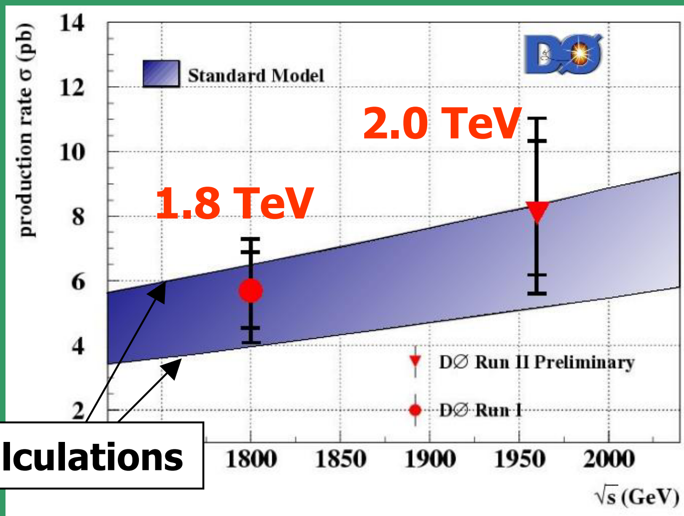
- search for surprises, anomalies?

Run II top candidate



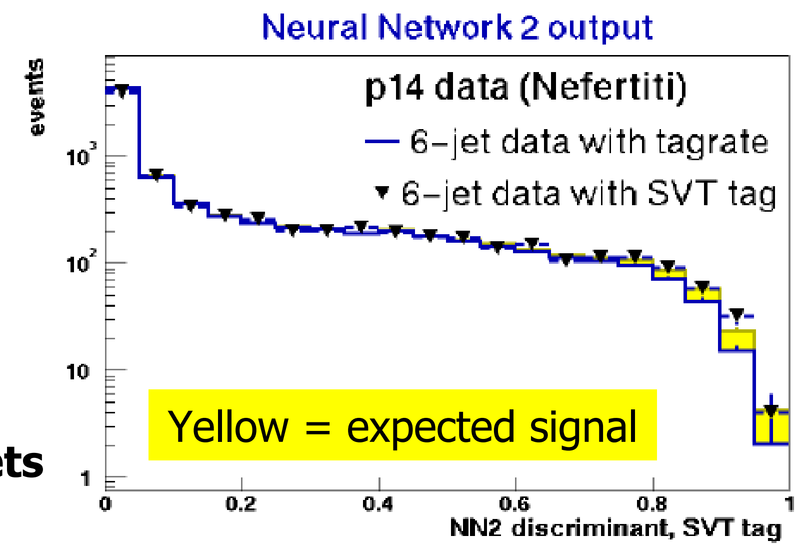
Top Production

Cross section is as expected from QCD



QCD calculations

We will update cross section measurements in the near future

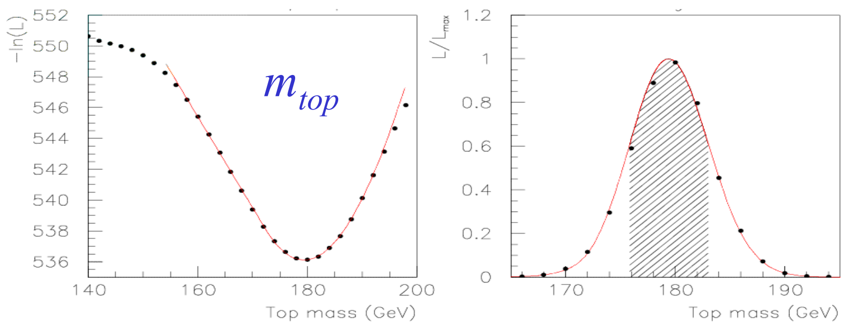


In progress
Top → all jets

New limits on single top also coming soon

Top mass

- **New DØ Run I lepton+ jets mass measurement (Δm = 5.4 GeV) equivalent to a factor 2.4 increase in statistics:**

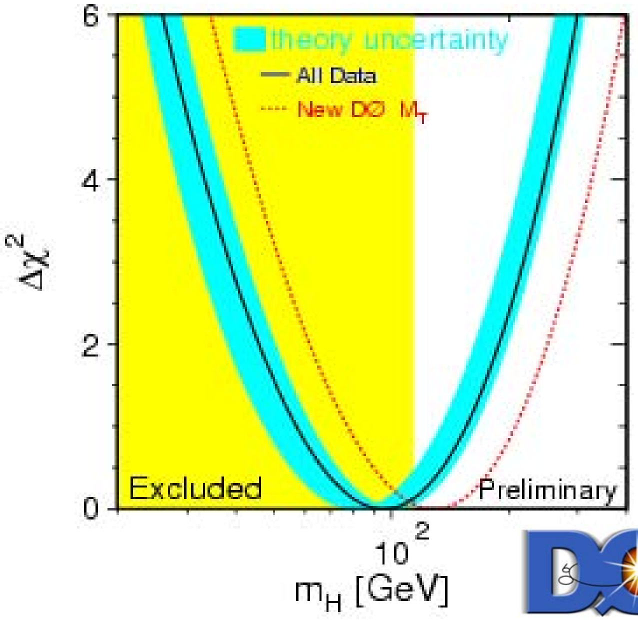


Run II mass analysis in progress, using this technique, the classic (Run I) technique, and a newly developed one
anticipated stat. error 6-8 GeV

DØ m_{top} = 179.0 ± 5.1 GeV (l+ jets and dilepton combined)

Precise m_{top} is important! *example…*

	Previous WA top mass	New DØ top mass
Higgs mass best fit	96 GeV + 60 - 38	123 GeV + 76 - 50
95% CL upper limit	219 GeV	277 GeV



The Higgs Sector

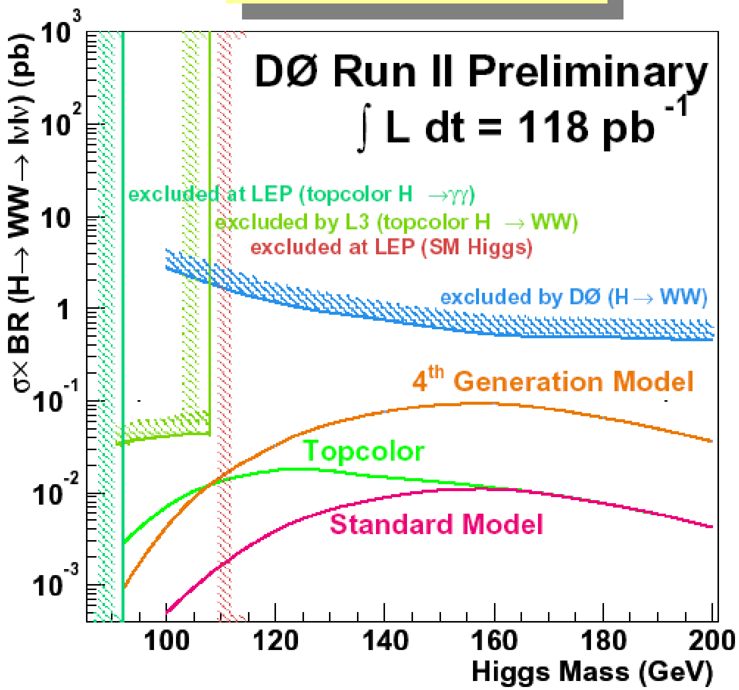
Discover (or exclude) scalar particles related to EWSB
Constrain their properties

The latest Tevatron luminosity plan makes it hard to cover the whole SM Higgs mass range, but we will do what we can — and the lowest masses (115 GeV!) are the most interesting

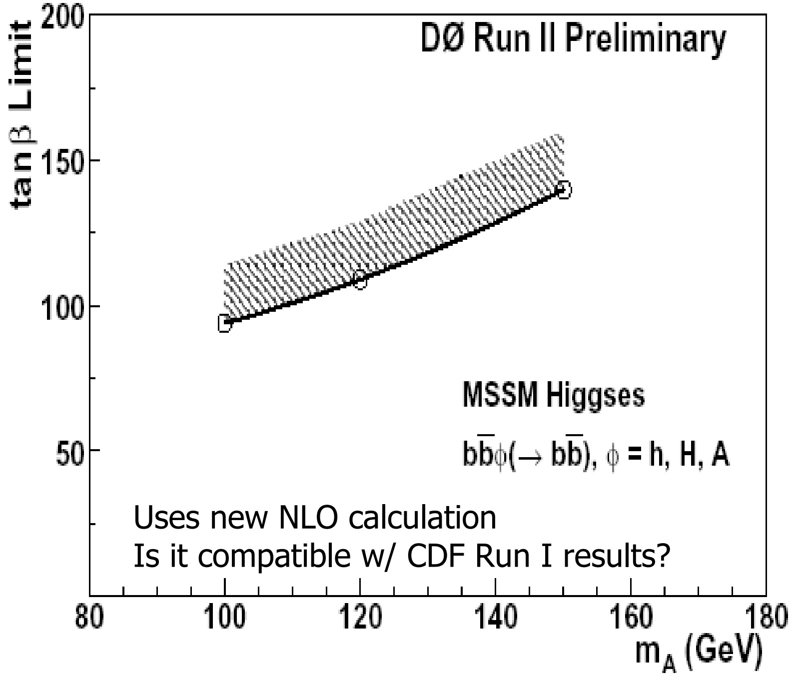
Higgs searches

- **With our current dataset, we don't expect to see a standard model Higgs signal**
  - **looking for nonstandard variants**
  - **developing our tools, our understanding, and ability to model backgrounds (e.g. W/Z +bb)**

H → WW search



SUSY (A/H/h)bb search



Also fermiophobic Higgs, doubly charged Higgs …

Searches

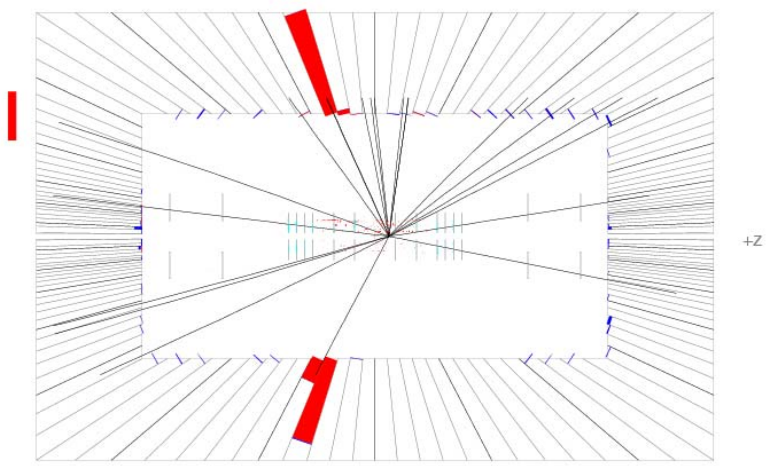
Find evidence for phenomena outside the SM
Improve constraints on such theories

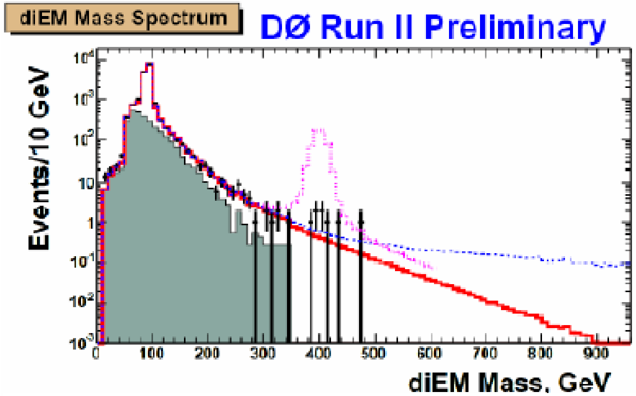
Searching for Extra Dimensions

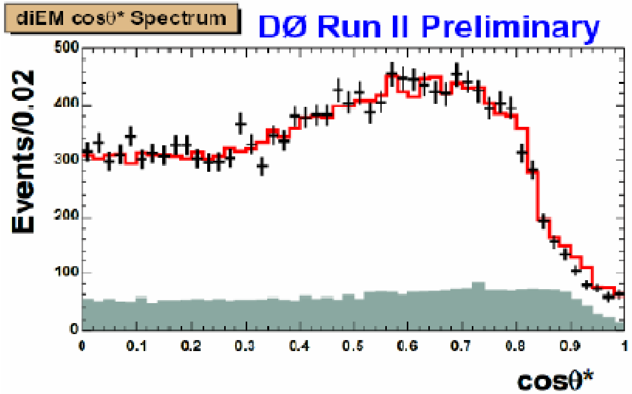
- Signal would be an excess of ee, $\mu\mu$, $\gamma\gamma$ events at large mass and large angle, due to virtual graviton exchange

High-mass electron pair event

mass = 475 GeV, cos θ^* = 0.01







Latest DØ limits from $\bar{p}p \rightarrow$ ee, $\mu\mu$, $\gamma\gamma$

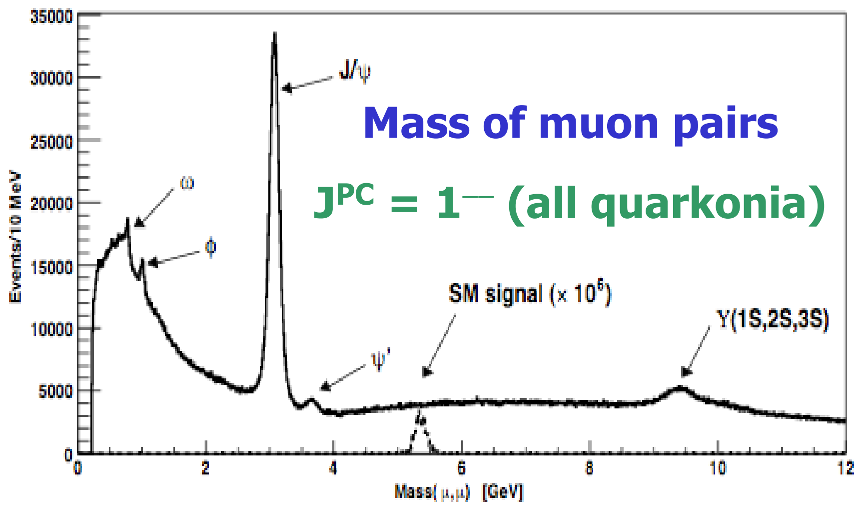
M_S(GRW) > 1.43 TeV (~ 200 pb^{-1}, 95% CL)

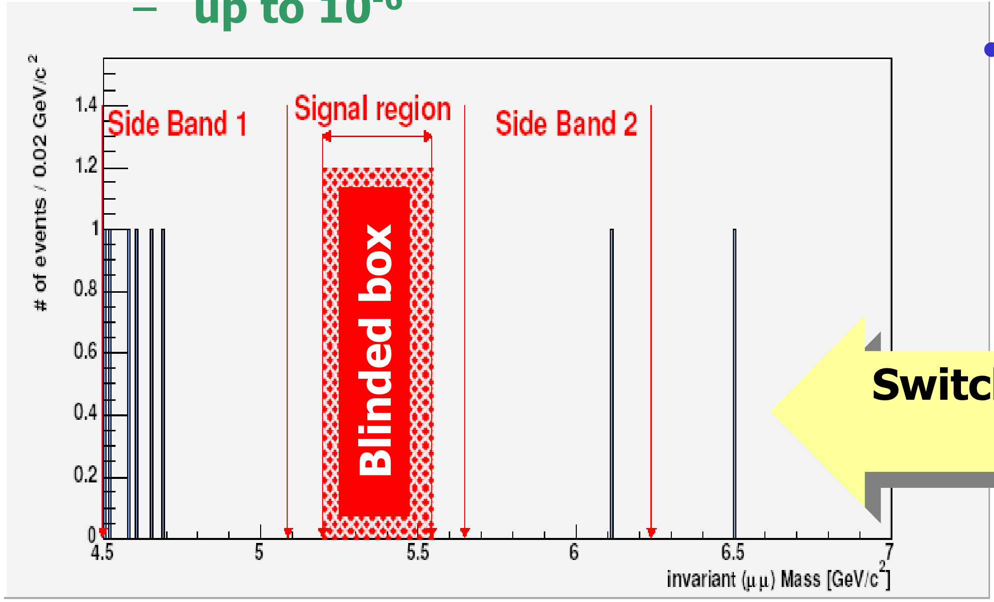
most stringent limit to date on large extra dimensions

Same dataset places limits on TeV-scale extra dimensions, Z′ …

Indirect searches for new particles

- **Measure the rate of the rare decay $B_s \to \mu^+\mu^-$**
- **In the Standard Model, cancellations lead to a very small branching ratio**
  - **SM BR= 3.7×10^{-9}**
- **New particles (e.g. SUSY) contribute additional Feynman diagrams, increase BR**
  - **up to 10^{-6}**





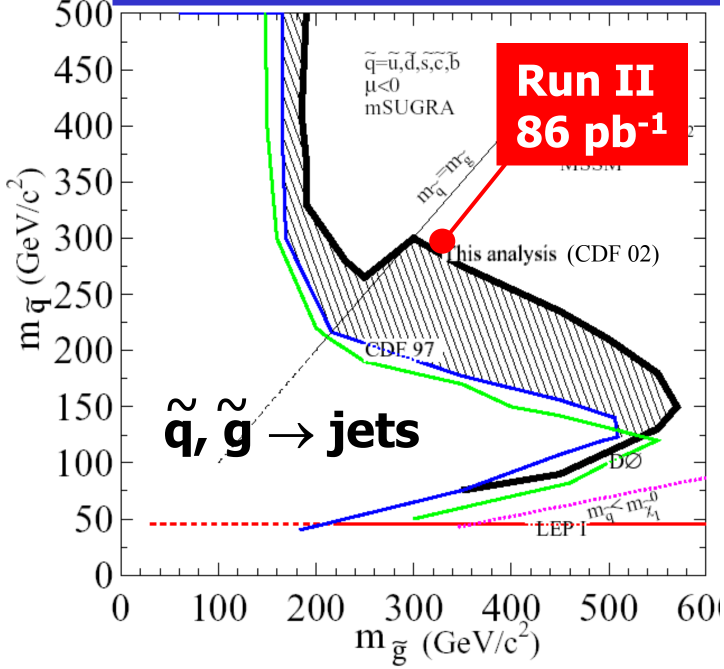
- **2003 result ($100 pb^{-1}$ of data)**
  - **Observed 3 events**
  - **Expect 3.4 ± 0.8 bkg.**
  - **BR ($B_s \to \mu^+\mu^-$) < 1.6×10^{-6} (90% CL)**

Switched to a blind analysis for summer 2004

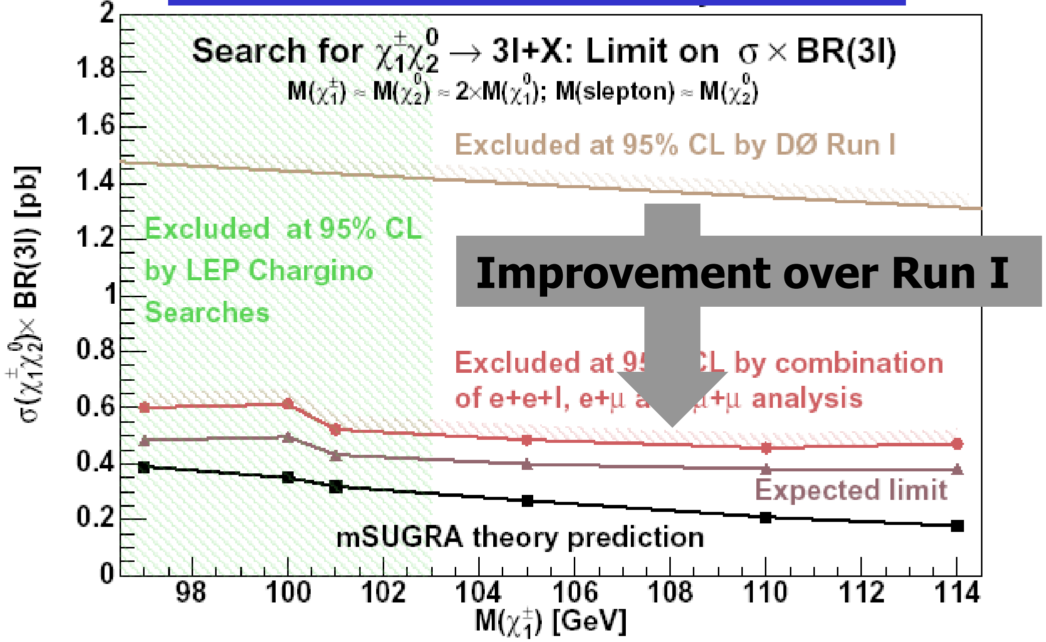
Still optimizing cuts; don't want to be biased

Direct supersymmetry searches

Squark/gluino production (Jets + missing E_T)



Chargino/neutralino production (dileptons and trileptons)



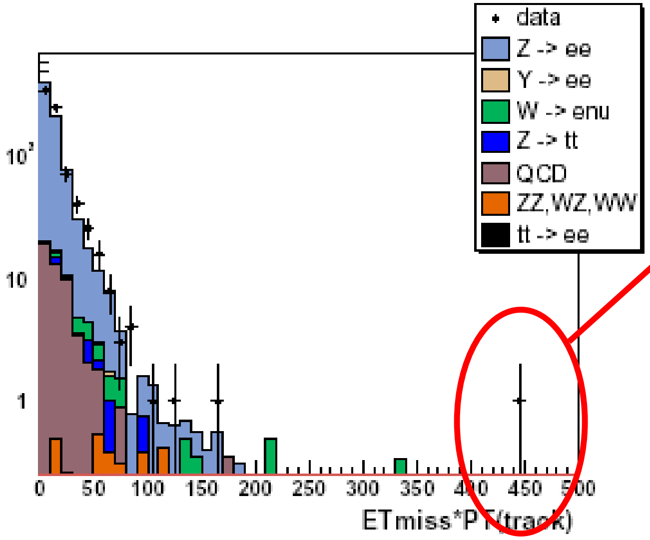
Also …

- **Gauge mediated SUSY (photons+ missing E_T)**
- **Stop searches**
- **R-parity violating searches …**

We have entered unexplored territory in terms of sensitivity to new physics

Things are starting to be fun

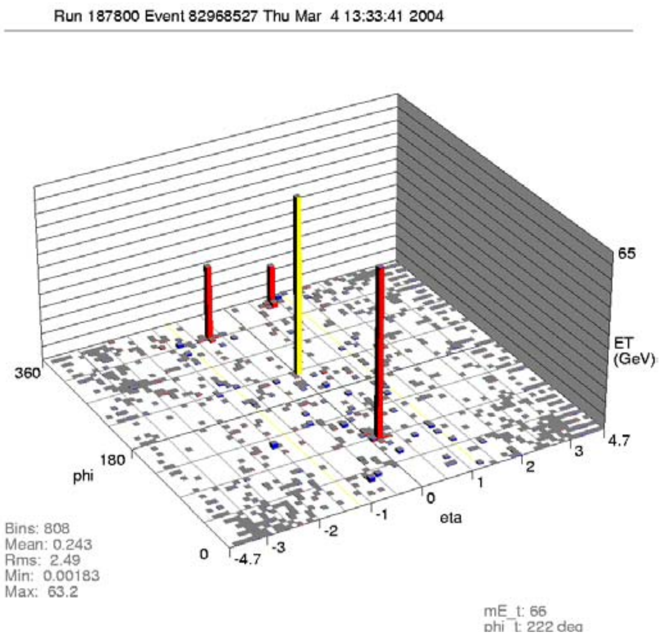
- **With 250 pb^{-1} in Run II, it is no longer crazy to imagine that new physics may be present in our data at the few event level**

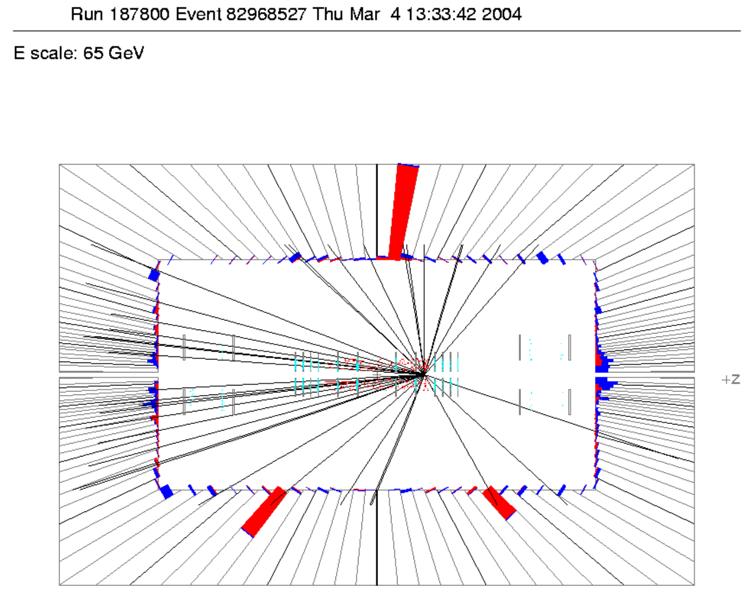


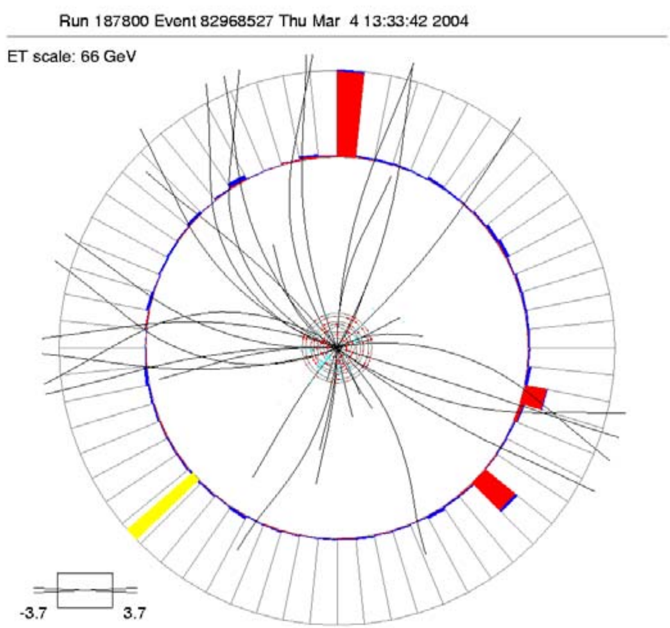
1 trilepton candidate event
Expected background fairly small
Expected SUSY signal 1-2 events

… also find
1 like-sign muon event
Expected background fairly small

... and more fun





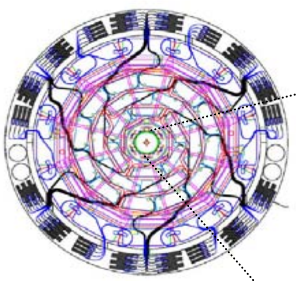


- **Gauge mediated SUSY search finds this intriguing $e\gamma\gamma$+ME$_T$ event**
  - **Mass of $\gamma\gamma$ = 86 GeV, but p$_T$ = 55 GeV/c**
    - **Unlikely to be a Z?**
  - **Transverse mass of e and ME$_T$ = 68 GeV**
    - **Consistent with a W**
- **What is the expected rate of $W\gamma\gamma$ production?**

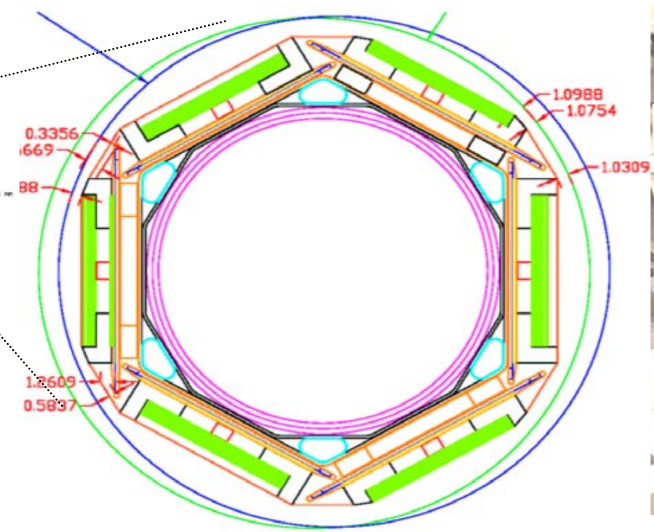
Prospects, plans

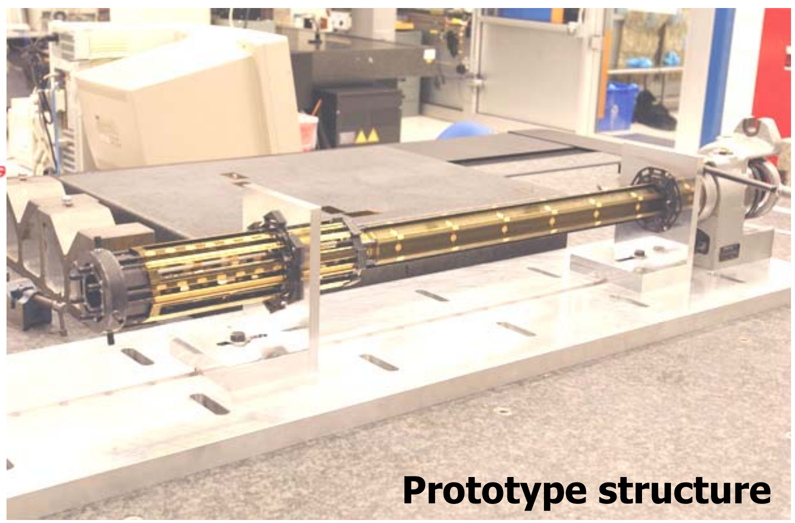
Detector Upgrades

- **In light of the financial and luminosity situation, the Fermilab director decided not to proceed with the CDF and DØ silicon detector upgrades**
- **In order to mitigate concerns over radiation damage and pattern recognition in DØ, we are constructing a new Silicon Layer 0**
  - **Fits inside the existing detector**
  - **Adds an additional radiation-hard tracking layer**
  - **Makes use of Run IIb R&D and technology**



Same diameter as a golf ball



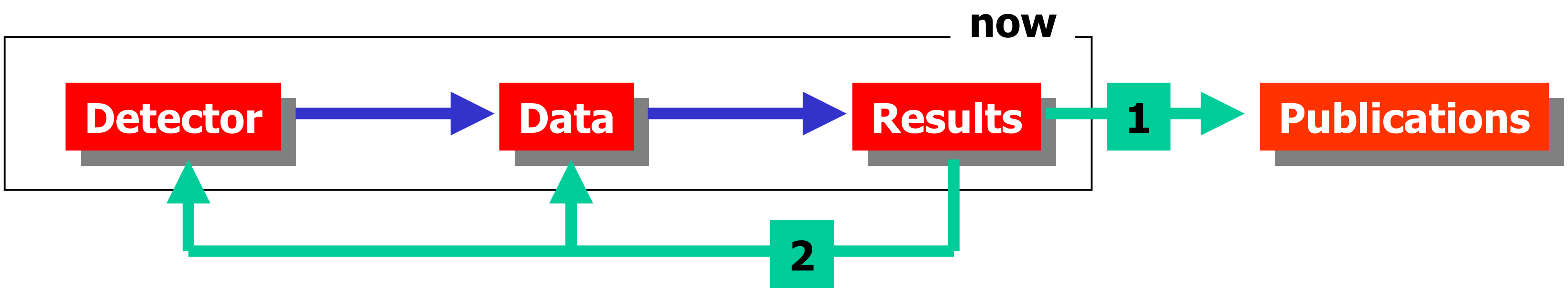


Prototype structure

- **Trigger upgrades remain as before (Calorimeter and Tracker)**

On track for installation of both silicon and trigger in Summer 2005

Goals and Challenges



- Also, we are starting to get to grips with
  - Upgrade installation/commissioning/physics process
    - Task force being set up
    - Some recent management changes to position ourselves (Jonathan Kotcher is now Technical Integration Coordinator)
  - Long term manpower needs for detector operations and analysis
    - HEPAP request

Conclusions

- The Run II physics program is unmatched in breadth and importance
- This physics program is based on the detailed understanding of Standard Model particles and forces that we have obtained over the last few decades
- Based on that understanding we can address some very big questions about the universe

  For example
  - What is the cosmic dark matter? (Supersymmetry?)
  - Is the universe filled with energy? (Higgs?)
  - What is the structure of spacetime? (Extra dimensions?)

  The Tevatron is in the only facility in operation that can do this

- The DØ detector is working well and the collaboration is enthusiastic
- We have entered unexplored territory—who knows what we will find!